UNITED STATES NAVAL
POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

CATALOGUE FOR 1965-1966

Clarence F. Klamm, Jr.

UNITED STATES NAVAL
POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

☆

CATALOGUE FOR 1965-1966

Herrmann Hall, Main Administration Building

MISSION

The Secretary of the Navy has defined the mission of the Naval Postgraduate School as follows:

"To conduct and direct the Advanced Education of commissioned officers, to broaden the professional knowledge of general line officers, and to provide such other indoctrination, technical and professional instruction as may be prescribed to meet the needs of the Naval Service; and in support of the foregoing, to foster and encourage a program of research in order to sustain academic excellence."

Superintendent

EDWARD JOSEPH O'DONNELL

Rear Admiral, U.S. Navy

B.S., USNA, 1929; NAVPGSCOL 1939

U. S. NAVAL POSTGRADUATE SCHOOL

Deputy Superintendent

HENRY FILLEDES LLOYD

Captain, U.S. Navy
B.S., USNA, 1939; NAVPGSCOL, 1945; M.S., MIT, 1946;
Industrial College of the Armed Forces, 1956

Academic Dean

Director of Programs

JOHN WILLIAM MURPH

Captain, U.S. Navy
B.A., Wofford College, 1939;
Naval War College, 1958

Dean of Programs

WILBERT FREDERICK KOEHLER

B.S., Allegheny College, 1933; M.A.,
Cornell Univ., 1934; Ph.D., Johns Hopkins Univ., 1948

Executive Assistant to the Director of Programs

JAMES JOSEPH MCMULLAN

Captain, U.S. Navy
B.A., St. Mary's College, 1941

Dean of Curricula

LAWRENCE EDWARD KINSLER

B.S., California Institute of Technology, 1931;
Ph.D., 1934

Dean of Admissions

BROOKS JAVINS LOCKHART

B.A., Marshall Univ., 1937; M.S., West
Virginia Univ., 1940; Ph.D., Univ. of Illinois, 1943

Dean of Research Administration

CARL ERNEST MENNEKEN

B.S., Univ. of Florida, 1932;
M.S., Univ. of Michigan, 1936

Head of Computer Facility

DOUGLAS GEORGE WILLIAMS

M.A. (honors), Univ. of Edinburgh, 1954

Superintendent's Staff Assistants

Aide to the Superintendent.....Lt Matthew A. McCarthy, usn
Plans Officer.....Cdr Jack Hilton, usn
Comptroller.....Capt Edward A. Sanford, Jr., sc, usn
Industrial Relations Officer.....Mr. John J. Coyle
Aviation Officer (OINC, NALF).....Capt Maximilian W. Munk, usn
Senior Medical Officer (NALF).....Lcdr Theodore J. Trumble, mc, usn
Marine Corps Representative.....Lt Col Alexander Kositch, usmc
Submarine Liaison Officer.....Cdr John P. Prisley, usn
Senior Chaplain.....Capt Thomas J. Burke, ChC, usn

Programs Administrative Staff

Registrar.....Mrs. Bessie Wilk
Class Scheduler.....Miss Elizabeth A. Kirby
Cataloguer.....Mrs. Bertha Ayers
Foreign Officer Coordinator.....Cdr George W. Fairbanks, usn
Flight Officer.....Cdr Edward D. Jackson, usn
Administrative Officer for Curricular Programs.....Lcdr Nancy L. Denton, usn
Program Allotment and Material Control Officer.....Lcdr John F. Campbell, usn

Administrative and Logistic Services

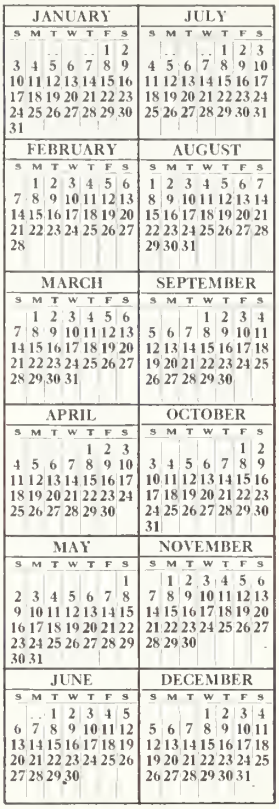
Director, Administrative and Logistics Services.....Capt John W. Shong, usn
Head, Administration Dept.....Cdr Phillip W. Nicholas, usn
Head, Supply Dept.....Cdr William F. Paulson, SC, usnr
Head, Public Works Dept.....Cdr Wayne S. Mitter, CEC, usn
Head, Dental Dept.....Capt Edmund H. Frizzell, DC, usn
Head, Services Dept.....Cdr Howard W. Carr, usn
Catholic Chaplain.....Capt Thomas J. Burke, ChC, usnr
Protestant Chaplain.....Capt Samuel D. Chambers, Jr., ChC, usnr
Public Information and Visit Liaison.....Cdr Lawrence R. Bemis, usn

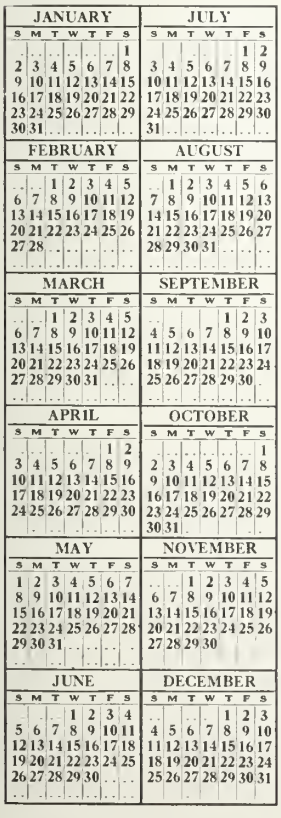
POSTGRADUATE SCHOOL CALENDAR

Academic Year 1965-1966

1965

"Elements of Management" summer course begins.....Monday, 28 June
Summer Term ends for Baccalaureate Curriculum.....Friday, 2 July
Fourth of July (Holiday).....Monday, 5 July
"Elements of Management" Course Ends.....Friday, 23 July
Registration for all curricular areas(except General Line).....Monday, 26 July
Fifth Terms Ends (1964-1965).....Thursday, 29 July
First Term Begins for all curricula (1965-1966).....Monday, 2 August
Graduation, Baccalaureate and Management Curriculum.....Tuesday, 3 August
Labor Day (Holiday).....Monday, 6 September
First Term Ends.....Thursday, 7 October
Second Term Begins.....Monday, 11 October
Graduation, General Line and Engineering Science.....Wednesday, 13 October
Veterans' Day (Holiday).....Thursday, 11 November
Thanksgiving Day (Holiday).....Thursday, 25 November
Second Term Ends; Christmas Holiday Begins.....Friday, 17 December
Registration for all curricula except Management, Data Processing, Nuclear Engr. (Eff.), and Engineering Electronics (CEC.).....Monday, 27 December





1966

Third Term begins for all curricula.....Monday, 3 January
Washington's Birthday (Holiday).....Tuesday, 22 February
Third Term Ends.....Thursday, 10 March
Fourth Term Begins.....Monday, 14 March
Graduation, Baccalaureate Curriculum.....Wednesday, 16 March
Fourth Term Ends.....Thursday, 19 May
Fifth Term Begins.....Monday, 23 May
Graduation, all technical curricula, Engineering Science (August 1965 input).....Friday, 27 May
Memorial Day (Holiday).....Tuesday, 31 May
Space and Astronautics Orientation Begins.....Wednesday, 22 June
Space and Astronautics Orientation Ends.....Friday, 24 June
"Elements of Management" summer course begins.....Monday, 27 June
Summer Term for Baccalaureate Curriculum Ends.....Friday, 1 July
Fourth of July (Holiday).....Monday, 4 July
"Elements of Management" summer course ends.....Friday, 22 July
Registration for all curricular areas.....Monday, 25 July
Fifth Term Ends (1965-1966).....Thursday, 28 July
First Term Begins (1966-1967).....Monday, 1 August
Graduation, Baccalaureate and Management curricula.....Wednesday, 3 August

DISTINGUISHED ALUMNI

Among those who have completed a postgraduate curriculum who attained flag (USN) or general (USMC) rank on the active list are the following: (The asterisk (*) indicates those on active list as of 1 April 1965.)

Admiral Walter F. Boone
Admiral Arleigh A. Burke
General Clifton B. Cates
Admiral Maurice E. Curts
Admiral Arthur C. Davis
Admiral Robert L. Dennison
Admiral Donald B. Duncan
Admiral Frank G. Fahrion
Admiral Cato D. Glover, Jr.
Admiral Roscoe F. Good
Admiral Charles D. Griffin*
Admiral Byron H. Hanlon
Admiral Royal E. Ingersoll
Admiral Albert G. Noble
Admiral Alfred M. Pride
Admiral James O. Richardson
Admiral Horacio Rivero, Jr.*
Admiral Samuel M. Robinson
Admiral James S. Russell
Admiral Ulysses S. G. Sharp, Jr.*
Admiral John H. Sides
General Holland M. Smith
Admiral Felix B. Stump
General Merrill B. Twining
Admiral Alfred G. Ward*
Admiral John M. Will
Vice Admiral Walter S. Anderson
Vice Admiral Harold D. Baker
Vice Admiral Wallace M. Beakley
Vice Admiral George F. Beardsley
Vice Admiral Donald B. Beary
Vice Admiral Frank E. Beatty
Vice Admiral Robert E. Blick, Jr.
Vice Admiral Charles T. Booth, II*
Vice Admiral Harold G. Bowen
Vice Admiral Roland M. Brainard
Vice Admiral Carleton F. Bryant
Vice Admiral Edmund W. Burrough
Vice Admiral William M. Callaghan
Vice Admiral John H. Carson
Vice Admiral Ralph W. Christie
Vice Admiral Edward W. Clexton
Vice Admiral Oswald S. Colclough
Vice Admiral John B. Colwell*
Vice Admiral Thomas S. Combs
Vice Admiral George R. Cooper
Vice Admiral William G. Cooper
Vice Admiral John C. Daniel
Vice Admiral Glenn B. Davis
Vice Admiral Harold T. Deutermann*
Vice Admiral Glynn R. Donaho*
Vice Admiral James H. Doyle
Vice Admiral Irving T. Duke
Vice Admiral Calvin T. Durgin
Vice Admiral Ralph Earle, Jr.
Vice Admiral Clarence E. Ekstrom
Vice Admiral Emmet P. Forrestel
Vice Admiral Roy A. Gano
Vice Admiral William E. Gentner, Jr.*
Vice Admiral Elton W. Grenfell
Lieutenant General Field Harris
Vice Admial Robert W. Hayler
Vice Admiral Truman J. Hedding
Lieutenant General Leo D. Hermle
Vice Admiral Ira E. Hobbs
Vice Admiral Ephraim P. Holmes*
Vice Admiral George F. Hussey, Jr.
Vice Admiral Olaf M. Hustvedt
Vice Admiral Thomas B. Inglis
Vice Admiral Andrew M. Jackson, Jr.*
Vice Admiral Albert E. Jarrell
Vice Admiral Harry B. Jarrett
Lieutenant General Clayton C. Jerome
Vice Admiral Robert T. S. Keith
Vice Admiral Ingolf N. Kiland
Vice Admiral Fred P. Kirtland
Vice Admiral Willard A. Kitts
Vice Admiral Harold O. Larson
Vice Admiral Ruthven E. Libby
Vice Admiral Frank L. Lowe
Vice Admiral Vernon L. Lowrance*
Vice Admiral James E. Maher
Vice Admiral William J. Marshall
Vice Admiral Charles B. Martell*
Vice Admiral Kleber S. Masterson*
Vice Admiral John L. McCrea
Vice Admiral Ralph E. McShane
Vice Admiral Charles L. Melson*
Vice Admiral Arthur C. Miles
Vice Admiral Milton E. Miles
Vice Admiral Earle W. Mills
Vice Admiral Marion E. Murphy
Vice Admiral Lloyd M. Mustin*
Vice Admiral Frank O'Beirne
Vice Admiral Francis P. Old
Vice Admiral Howard E. Orem
Vice Admiral Harvey E. Overesch
Vice Admiral Edward N. Parker
Vice Admiral Frederick W. Pennoyer, Jr.
Vice Admiral Charles A. Pownall
Vice Admiral Thomas C. Ragan
Vice Admiral Lawson P. Ramage*
Vice Admiral William L. Rees
Vice Admiral Robert H. Rice
Vice Admiral Hyman G. Rickover*
Vice Admiral Rufus E. Rose
Vice Admiral Richard W. Ruhle
Vice Admiral Theodore D. Ruddock, Jr.
Vice Admiral Lorenzo S. Sabin, Jr.
Vice Admiral Harry Sanders
Vice Admiral Walter G. Schindler
Vice Admiral William A. Schoech
Vice Admiral Harry E. Sears
Vice Admiral Thomas G. W. Settle
Vice Admiral William B. Smedberg, III
Vice Admiral Allan E. Smith
Vice Admiral Chester C. Smith
Vice Admiral Roland N. Smoot
Lieutenant General Edward W. Snedeker
Vice Admiral Selden B. Spangler
Vice Admiral Thomas M. Stokes
Vice Admiral Paul D. Stroop*
Lieutenant General James A. Stuart
Vice Admiral Wendell G. Switzer
Vice Admiral John Sylvester
Vice Admiral Aurelius B. Voseller
Vice Admiral Homer N. Wallin
Vice Admiral James H. Ward
Vice Admiral Charles E. Weakley*
Vice Admiral Charles Wellborn, Jr.
Vice Admiral George L. Weyler
Vice Admiral Charles W. Wilkins
Vice Admiral Ralph E. Wilson
Vice Admiral Chester C. Wood
Vice Admiral George C. Wright
Rear Admiral John W. Ailes, III*
Rear Admiral Frank Akers
Rear Admiral Jackson D. Arnold*
Rear Admiral Frederick L. Ashworth*
Rear Admiral Edgar H. Batcheller*
Rear Admiral Richard W. Bates
Rear Admiral Frederick J. Becton*
Read Admiral David B. Bell*
Rear Admiral Fred G. Bennett*
Rear Admiral Rawson Bennett, II
Rear Admiral Abel T. Bidwell
Major General Arthur F. Binney
Rear Admiral Calvin M. Bolster
Rear Admiral Harold G. Bowen, Jr.*
Rear Admiral Frank A. Braisted
Rear Admiral Harold M. Briggs
Rear Admiral William A. Brockett*
Rear Admiral Charles B. Brooks, Jr.
Rear Admiral James A. Brown*
Rear Admiral Henry C. Bruton
Rear Admiral Louis A. Bryan*
Rear Admiral Charles A. Buchanan
Rear Admiral Thomas Burrowes
Rear Admiral Robert L. Campbell
Rear Admiral Milton O. Carlson
Rear Admiral Worrall R. Carter
Rear Admiral Robert W. Cavenagh*
Rear Admiral Lester S. Chambers*
Rear Admiral John L. Chew*
Rear Admiral Ernest E. Christensen*
Rear Admiral David H. Clark
Rear Admiral Henry G. Clark, CEC
Rear Admiral Sherman R. Clark
Rear Admiral Leonidas D. Coates, Jr.
Rear Admiral Howard L. Collins
Rear Admiral Thomas F. Connolly*

Rear Admiral Joshua W. Cooper
Rear Admiral Roy T. Cowdrey
Rear Admiral Ormond L. Cox
Rear Admiral Richard S. Craighill*
Rear Admiral Frederick G. Crisp
Rear Admiral Robert E. Cronin
Rear Admiral Charles A. Curtze*
Rear Admiral Lawrence R. Daspit*
Rear Admiral James R. Davis, CEC*
Rear Admiral James W. Davis*
Rear Admiral James C. Dempsey*
Rear Admiral Joseph E. Dodson
Rear Admiral William A. Dolan, Jr.
Rear Admiral Marshall E. Dornin*
Rear Admiral Jack S. Dorsey*
Rear Admiral Jennings B. Dow
Rear Admiral Wallace R. Dowd
Rear Admiral Louis Dreller
Rear Admiral Norman J. Drustrup, CEC*
Rear Admiral Clifford H. Duerfeldt
Rear Admiral Charles A. Dunn
Rear Admiral Donald T. Eller
Rear Admiral Robert B. Ellis
Rear Admiral Edward J. Fahy*
Rear Admiral James M. Farrin, Jr.*
Rear Admiral Emerson E. Fawkes*
Rear Admiral John J. Fee*
Rear Admiral William E. Ferrall
Rear Admiral Charles W. Fisher
Rear Admiral Henry C. Flanagan
Rear Admiral Eugene B. Fluckey*
Rear Admiral Mason B. Freeman*
Rear Admiral Laurence H. Frost
Rear Admiral Robert B. Fulton, II*
Rear Admiral Julius A. Furer
Rear Admiral Daniel V. Gallery
Rear Admiral Robert O. Glover
Rear Admiral Willard K. Goodney
Rear Admiral Arthur R. Gralla*
Rear Admiral Lucien McK. Grant
Rear Admiral Edward E. Grimm*
Rear Admiral Peter W. Haas, Jr.
Rear Admiral Ira F. Haddock, SC*
Rear Admiral Frederick E. Haeberle
Rear Admiral Welsey M. Hague
Rear Admiral Grover B. H. Hall
Rear Admiral Lloyd Harrison
Rear Admiral Hugh E. Haven
Rear Admiral Frederick V. H. Hilles*
Rear Admiral Wellington T. Hines*
Rear Admiral Morris A. Hirsch*
Rear Admiral George A. Holderness, Jr.
Rear Admiral Ralston S. Holmes
Rear Admiral Ernest C. Holtzworth
Rear Admiral Leroy V. Honsinger
Rear Admiral Edwin B. Hooper*
Rear Admiral Harold A. Houser
Rear Admiral Herbert S. Howard
Rear Admiral Miles H. Hubbard
Rear Admiral Harry Hull*
Rear Admiral James McC. Irish
Rear Admiral William D. Irvin*
Rear Admiral Joseph A. Jaap*
Major General Samuel S. Jack
Major General Arnold W. Jacobsen
Rear Admiral Ralph K. James
Rear Admiral Frank L. Johnson*
Rear Admiral Horace B. Jones, CEC
Rear Admiral Timothy J. Keleher
Rear Admiral Sherman S. Kennedy
Rear Admiral Husband E. Kimmel
Rear Admiral Grover C. Klein
Rear Admiral Denys W. Knoll*
Rear Admiral Sydney M. Kraus
Rear Admiral Thomas R. Kurtz, Jr.
Rear Admiral David Lambert*
Major General Frank H. Lamson-Scribner
Rear Admiral Martin J. Lawrence
Rear Admiral William H. Leahy
Rear Admiral Joseph W. Leverton, Jr.
Rear Admiral John K. Leydon*
Rear Admiral Theodore C. Lonnquest
Rear Admiral Almon E. Loomis
Rear Admiral Wayne R. Loud
Rear Admiral Charles H. Lyman, III*
Major General William G. Manley
Rear Admiral Charles F. Martin
Rear Admiral John B. McGovern
Rear Admiral Eugene B. McKinney
Rear Admiral Kenmore M. McManes
Rear Admiral John H. McQuilken*
Rear Admiral William K. Mendenhall, Jr.
Major General Lewie G. Merritt
Rear Admiral William Miller
Rear Admiral Benjamin E. Moore*
Rear Admiral Robert L. Moore, Jr.*
Rear Admiral Armand M. Morgan
Rear Admiral Thomas H. Morton
Rear Admiral Albert G. Mumma
Rear Admiral Joseph N. Murphy
Rear Admiral William T. Nelson*
Rear Admiral Charles A. Nicholson, II
Rear Admiral Robert H. Northwood, SC*
Rear Admiral Ira H. Nunn
Rear Admiral Emmet O'Beirne
Rear Admiral Edward J. O'Donnell*
Rear Admiral Clarence E. Olsen
Rear Admiral Ernest M. Pace
Rear Admiral Charles J. Palmer
Rear Admiral Lewis S. Parks
Rear Admiral Goldsborough S. Patrick
Rear Admiral John B. Pearson, Jr.
Rear Admiral Henry S. Persons*
Rear Admiral William F. Petrovic*
Rear Admiral Carl J. Pfingstag
Rear Admiral Richard H. Phillips
Rear Admiral Paul E. Pihl
Rear Admiral Frank L. Pinney, Jr.*
Rear Admiral Walter H. Price*
Rear Admiral Schuyler N. Pyne
Rear Admiral John Quinn
Rear Admiral Joseph R. Redman
Rear Admiral Harry L. Reiter, Jr.*
Rear Admiral Henry A. Renken*
Rear Admiral Joseph E. Rice*
Rear Admiral Lawrence B. Richardson
Rear Admiral Basil N. Rittenhouse, Jr.
Rear Admiral Walter F. Rodee
Rear Admiral William K. Romoser
Rear Admiral Gordon Rowe
Rear Admiral Donald Royce
Rear Admiral Edward A. Ruckner*
Rear Admiral George L. Russell
Rear Admiral Dennis L. Ryan
Rear Admiral Ben W. Sarver*
Rear Admiral Malcolm F. Schoeffel
Rear Admiral Floyd B. Schultz*
Rear Admiral John N. Shaffer*
Rear Admiral William B. Sieglaff*
Rear Admiral Harry Smith*
Rear Admiral John V. Smith*
Rear Admiral Levering Smith*
Rear Admiral John A. Snackenberg
Rear Admiral Philip W. Snyder
Rear Admiral Thorvald A. Solberg
Rear Admiral Edward A. Solomons
Rear Admiral Robert H. Speck*
Rear Admiral Frederick C. Stelter, Jr.
Rear Admiral Edward C. Stephan
Rear Admiral Earl E. Stone
Rear Admiral Charles W. Styer
Rear Admiral Robert L. Swart
Rear Admiral William E. Sweeney*
Rear Admiral Evander W. Sylvester
Rear Admiral Frank R. Talbot
Rear Admiral Raymond D. Tarbuck
Rear Admiral Arthur H. Taylor*
Rear Admiral John McN. Taylor*
Rear Admiral Theodore A. Torgerson*
Rear Admiral George C. Towner
Rear Admiral Robert L. Townsend*
Rear Admiral David M. Tyree
Rear Admiral Alexander H. Van Keuren
Rear Admiral Frank Virden
Rear Admiral George H. Wales
Rear Admiral Frederick B. Warder
Rear Admiral William W. Warlick
Rear Admiral Odale D. Waters, Jr.*
Rear Admiral Hazlett P. Weatherwax
Rear Admiral Charles D. Wheelock
Rear Admiral Francis T. Williamson*
Rear Admiral Frederick S. Withington
Rear Admiral Edward A. Wright
Rear Admiral Howard A. Yeager*
Rear Admiral Elmer E. Yeomans
Commodore Harry A. Badt
Commodore Harold Dodd
Brigadier General Edward C. Dyer
Commodore Stanley D. Jupp
Commodore John H. Magruder, Jr.
Brigadier General Keith B. McCutcheon*
Brigadier General Ivan W. Miller
Commodore Robert E. Robinson, Jr.
Commodore Henry A. Schade
Commodore Oscar Smith
Commodore Ralph S. Wentworth

Rear Admiral Selectees:

Capt John E. Dacey*
Capt Philip A. Beshany*
Capt Vincent P. de Poix*
Capt Robert W. McNitt*
Capt Ralph Weymonth*
Capt Thomas J. Walker, III*

HISTORY

The U. S. Naval Postgraduate School had a modest beginning at the Naval Academy at Annapolis in 1909, at which time the first class of ten officers enrolled in a Marine Engineering curriculum. The need for technically educated officers became evident at the turn of the century. The idea of a naval graduate school had its inception in a course of instruction in Marine Engineering which the Bureau of Engineering instituted in 1904. The results of this course were so encouraging that in 1909 the Secretary of the Navy established a School of Marine Engineering at the Naval Academy in Annapolis. In 1912 the School was designated the Postgraduate Department of the U. S. Naval Academy.

The operation of the school was temporarily suspended during World War I, but in 1919 classes were resumed in converted Marine Barracks on the Naval Academy grounds. At this time curricula in Mechanical Engineering and Electrical Engineering were added. With the passing years other curricula—Ordnance Engineering, Radio Engineering, Aerological Engineering and Aeronautical Engineering—were added as the Navy's need for officers with technical knowledge in these fields became evident.

In 1927 the General Line Curriculum was established within the Postgraduate School to provide courses of instruction to acquaint junior line officers returning from sea duty with modern developments taking place in the Navy. The courses dealt with naval and military subjects for the most part. The General Line Curriculum remained as an integral part of the Postgraduate Department until the declaration of the emergency prior to the outbreak of World War II, at which time it was discontinued because of the need for officers in the growing fleet.

The enrollment in the Postgraduate School increased rapidly in the war years both in the several engineering curricula and in the communications curriculum which was added to meet the need for trained communication officers in the naval establishment. The School outgrew its quarters necessitating the building of an annex to house the additional classrooms and laboratories required, but even with this addition, the space requirements of the expanded school were not met.

The post-war program called for still further expansion and the re-establishment of the General Line Curriculum with a greatly increased enrollment. In 1946 the General Line School was established at Newport, Rhode Island, as an outlying element of the Postgraduate School and continued until disestablished in 1952; in 1948 an additional General Line School was established at Monterey, California. The objective of the General Line School program—that of providing an integrated course in naval science to broaden the professional knowledge of unrestricted line officers of the Regular Navy—continued in effect as it had since the inception of this program. From 1946 until 1955 a curriculum varying in length from six months to one year provided such a course for Reserve and ex-Temporary officers who had transferred to Regular status. From 1955 to 1962, the curriculum was of nine and one-half months duration.

The physical growth of the School and its increase in scope and importance were recognized in Congressional action which resulted in legislation during the years of 1945 to 1951 emphasizing the academic stature of the School, and providing for continued growth in a new location with modern buildings and equipment. This legislation authorized the Superintendent to confer Bachelor's, Master's, and Doctor's degrees in engineering and related subjects; created the position of Academic Dean to insure continuity in academic policy; established the School as a separate naval activity to be known as the United States Naval Postgraduate

School; authorized the establishment of the School at Monterey, California; provided funds to initiate the construction of buildings to house modern laboratories and classrooms at that location.

On 22 December 1951, by order of the Secretary of the Navy, the United States Naval Postgraduate School was officially disestablished at Annapolis, Maryland, and established at Monterey, California. This completed the transfer of the School from the East to the West Coast, which had begun in 1948 when Aerology Department and Curricular office were moved to the new location. Concurrently with this relocation, the U. S. Naval School (General Line) at Monterey was disestablished as a separate military command and its functions and facilities were assumed by the U. S. Naval Postgraduate School. At the same time, there was established the U. S. Naval Administrative Command, U. S. Naval Postgraduate School, Monterey, to provide logistic support, including supply, public works, medical and dental functions, for the Naval Postgraduate School and its components.

In June 1956, by direction of the Chief of Naval Personnel, the Navy Management School was established as an additional component of the Postgraduate School. Its mission was to provide an educational program for officers in the application of sound scientific management practice to the complex organizational structure and operation of the Navy with a view to increasing efficiency and economy of operation. The first class included only Supply and Civil Engineering Corps officers and emphasis was placed on general management theory, financial management, and inventory management. In August 1957 this school was expanded to include input from both Line and Staff Corps officers. Since that time the curriculum has been under constant revision to include new areas of import to, and changes of concept in, the field of management. In August 1960 the school curriculum was lengthened from a five to a ten month course leading to a master's degree for those who can meet the requirements for such a degree. Commencing in August 1964 the Management Curriculum was lengthened from a four to a five term course, thus requiring 12 months for completion.

Discussions commenced in mid-1957 resulted in the establishment in August 1958 of a Bachelor of Science curriculum in the General Line School and a change in the name of that school, effective 1 July 1958, to the General Line and Naval Science School. The new curriculum, with planned semi-annual input of 50 officers, was to become a part of the Navy's Five-Term Program, with the long range prospect of having the entire program carried out at Monterey.

The curriculum was to include subjects taught in the General Line curriculum plus new courses adequate in number, level, and scope to support a degree of bachelor of science, no major designated. The success of the program through the early classes led to the addition of an Arts program in August 1961 to provide for those officers whose previous education emphasized the humanities rather than science and mathematics.

The continuing growth and projected expansion of the School led the Superintendent to establish, in the fall of 1961, a special group of staff and faculty members to study internal organization. The outgrowth of this study coupled with further deliberations of the Superintendent and other staff and faculty members was the decision to undergo major reorganization. In June 1962, the Administrative Command was disestablished as a separate command, its functions continuing to be performed by personnel reporting to a new Director of Administrative and Logistic Services. In August 1962, the three component schools were disestablished and a completely new organization became effective. There is now but one School—the U. S. Naval Postgraduate School—with unified policy, procedure, and purpose. The position of Chief of Staff was replaced by Deputy Superintendent and responsibility for the operation of the academic programs was placed under the dual control of a naval officer Director of Programs and a civilian Dean of Programs.

ORGANIZATION AND FUNCTIONS

The Superintendent of the Postgraduate School is a rear admiral of the line of the Navy. His principal assistants are a Deputy Superintendent who is a captain of the line, and an Academic Dean who is the senior member of the civilian faculty.

The academic programs and direct supporting functions are administered and operated through a unique organization composed of Curricular Offices and Academic Departments. The former are staffed by naval officers whose primary functions are threefold: (1) academic and military supervision and direction of officer students; (2) coordinating, in conjunction with Academic Associates, the elements of each curriculum within their program areas; and (3) conducting liaison with curricula sponsor representatives. Officer students are grouped into the following curricular programs areas:

Acronautical Engineering
Electronics and Communications Engineering
Ordnance Engineering
Naval Engineering
Environmental Sciences
Naval Management and Operations Analysis
Engineering Science
General Line and Baccalaureate

Officer students in each curricular group pursue similar or closely related curricula. With most of these areas a common core program of study is followed for at least half the period of residency.

Objectives and details of curricula are contained elsewhere in this catalogue.

The teaching functions of classroom and laboratory instruction and thesis supervision are accomplished by a faculty which is organized into eleven academic departments:

Aeronautics
Business Administration and Economics
Electrical Engineering
Government and Humanities
Material Science and Chemistry
Mathematics
Mechanical Engineering
Meteorology and Oceanography
Naval Warfare
Operations Analysis
Physics

Approximately two-thirds of the teaching staff are civilians of varying professorial rank and the remainder naval officers. The latter are spread amongst most of the departments with the majority being in the Department of Naval Warfare which offers courses only in the naval professional area.

Detailed listings of faculty members and course offerings are contained in later sections of the catalogue.

The Academic Program organization just described is tied together at the top by a naval officer Director of Programs and a civilian Dean of Programs who collaborate to share jointly the responsibilities for planning, conduct and administration of the several educational programs. An Executive Assistant to the Director of Programs similarly shares curricular responsibilities with a Dean of Curricula in a position just above the Curricular Officers.

The close tie between elements of this dual organization is further typified by the Academic Associates. These are individual civilian faculty members appointed by the Academic Dean to work closely with the Curricular Officers in the development and continuing monitoring of curricula — the Navy's needs being the responsibility of the Curricular Officer and academic soundness being the responsibility of the Academic Associate.

The educational programs conducted at Monterey fall into several general categories:

a. Engineering and scientific education leading to designated baccalaureate and/or advanced degrees.

b. Management education to the Master's level.

c. Undergraduate education leading to a first baccalaureate degree, either B.S. or B.A.

d. Navy professional type education designed to build upon and/or broaden the base of professional experience.

Supplementing category a. above is a program entitled Engineering Science. The major portion of the officers selected for this program undergo two terms of refresher and prerequisite study. Those who are so motivated and available for the requisite time may be selected by the Superintendent for a two or three year engineering or science curriculum. Those not selected continue in a non-degree program with the primary objective of basic scientific education which will better prepare them for advanced functional training and/or general updating in technical areas.

Logistic service support is rendered by conventional departments such as Supply and Disbursing, Public Works, Dental, Public Information and Visit Liaison, etc., grouped organizationally under a Director of Administrative and Logistic Services. Certain other offices such as those of the Comptroller and Plans are directly responsible to the Deputy Superintendent in a slightly modified but typical naval staff organization.

FACILITIES

The School is located about one mile east of downtown Monterey on the site of the former Del Monte Hotel. Modern classroom and laboratory buildings have been constructed and are situated on a beautifully landscaped campus. A group of buildings comprising new Aeronautical Propulsion Laboratories has recently been completed.

The Superintendent and central administrative officers are located in the main building of the former hotel, now called Herrmann Hall. The East wing of the main building complex has been converted into classroom and administrative spaces and a portion of the ground floor of the West wing has been similarly converted.

Spanagel, Bullard, Halligan, and Root Halls are modern buildings which are devoted to classroom, laboratory and

faculty office space. About one-third of the last named houses the Library and Reference Center. A fifth new building of matching architectural style is King Hall — the main auditorium.

Additional smaller buildings spread throughout the campus house specialized laboratory facilities as well as various support activities.

STUDENT AND DEPENDENT INFORMATION

Monterey Peninsula and the cities of Monterey, Carmel, Pacific Grove, and Seaside, all within 5 miles of the School, provide community support for the officers of the Postgraduate School.

La Mesa Village, located 3 miles from the School, consisting of former Wherry Housing and new Capehart Housing, contains 608 units of public quarters for naval personnel. An elementary school is located within the housing area.

The Naval Auxiliary Landing Field is located about one mile from the School. Aircraft are available for maintaining flight proficiency. Cross-country flights up to 1200 miles are now permitted. One half-day each week is scheduled for flying as part of the student work-week.

On the main School grounds are 149 BOQ rooms, an Open Mess, a Navy Exchange, 4 tennis courts, a large swimming pool and 6 lane bowling alley. An eighteen-tee nine-hole golf course has been built and opened on 1 April 1963. It is located in the old polo ground area across the street from the main campus.

Medical facilities include a Dispensary at the Naval Auxiliary Landing Field, Monterey, supported by the U. S. Army Hospital, Fort Ord (7 miles away) and the U. S. Navy Hospital at Oakland (120 miles away). A Dental Clinic is located in Herrmann Hall.

ADMISSIONS PROCEDURES

U. S. Navy officers interested in admission to one of the curricula offered at the Postgraduate School are referred to BuPers Notice 1520, Subject: Postgraduate and Undergraduate Education Programs, which is published annually by the Chief of Naval Personnel. This directive outlines the various educational programs available and indicates the method of submitting requests for consideration for each program.

A selection board is convened annually by the Chief of Naval Personnel to select officers, based upon professional performance, academic background, and ability, within quotas which reflect the Navy's requirements in the various fields of study available. Officers will be notified of selection by a BuPers Notice at the earliest feasible date after the meeting of the selection board, or by official correspondence.

The curriculum numbers as assigned in the annual BuPers Notice 1520 are repeated in the title of each curriculum and are also included in the list of curricula at the Postgraduate School on page 24 and the list of curricula conducted at civilian institutions on page 52.

Officers on duty with other branches of service are eligible to attend the Postgraduate School. They should apply in accordance with the directives promulgated by the Department of the Army, Department of the Air Force, Commandant U. S. Marine Corps, or the Commandant U. S. Coast Guard, as appropriate.

DEGREES, ACCREDITATIONS, AND ACADEMIC STANDARDS

The Superintendent is authorized to confer Bachelor's, Master's or Doctor's degrees in engineering or related fields upon qualified graduates of the School. This authority is subject to such regulations as the Secretary of the Navy may prescribe, contingent upon due accreditation from time to time by the appropriate professional authority of the applicable curricula. Recipients of such degrees must be found qualified by the Academic Council in accordance with prescribed academic standards.

The Naval Postgraduate School was accredited in 1962 as a full member of the Western College Association (WCA). Initial accreditation as an associate member was given in 1955 and was renewed in 1959 and 1964. Specific engineering curricula have been accredited by the Engineer's Council for Professional Development (ECPD), originally in 1949, renewed in 1955 and again in 1959.

The term length at the School is 10 weeks. The School's term credit hours are equivalent to two-thirds semester hours, as compared with schools using semesters of 15-16 weeks.

Students' performance is evaluated on the basis of a quality point number assigned to the letter grade achieved in a course, as follows:

Performance	*Grade*	*Quality Point Number*
Excellent	A	3.0
Good	B	2.0
Fair	C	1.0
Barely Passing	D	0.0
Failure	X	—1.0

When the term hours value of a course is multiplied by the quality point number of the student's grade, a quality point value for the student's work in that course is obtained. The sum of the quality points for all courses divided by the sum of the term hour value of all courses gives a weighted numerical evaluation of the student's performance termed the Quality Point Rating (QPR). A student achieving a QPR of 2.0 has maintained a B average in all courses undertaken with a proper weight assigned for course hours. Satisfactory academic proficiency at the Naval Postgraduate School has been established at a QPR of 1.0 for all courses of a curriculum.

Officer students have no major duties beyond applying themselves diligently to their studies. It is expected that students will maintain a high level of scholarship and develop attributes which are associated with a scholar seeking knowledge and understanding. Program schedules are such that the student should anticipate spending several hours

in evening study each weekday to supplement time available for this purpose between classes.

Courses listed in this catalogue carry a letter designator following the course number to indicate the kind of credit received for the successful completion of that course as follows:

A Graduate Credit
B Graduate or Undergraduate Credit
C Upper Division Credit
D Lower Division Credit
E No credit.

The two numbers in parenthesis (separated by hyphens) following the course title indicate the hours of instruction per week in classroom and laboratory respectively. Laboratory hours are assigned half the value shown in calculating term hours for the credit value of the course. Thus a (3-2) course (having three hours recitation and two hours laboratory) will be assigned a credit vaue of 4 term hours.

DIPLOMAS OF COMPLETION

Diplomas of Completion are issued to students completing programs which do not offer a degree. To establish eligibility for a Diploma of Completion, a student must obtain an over-all QPR of 1.0 or better. Where applicable, students obtaining a QPR of 2.75 or better will receive Diplomas of Completion "With Distinction."

REQUIREMENTS FOR THE BACCALAUREATE DEGREE

1. A Bachelor's degree may be awarded for successful completion of a curriculum which has the approval of the Academic Council as meriting the degree. Such curricula shall conform to current practice in accredited institutions and shall contain a well defined major.

2. Admission with suitable advanced standing and a minimum of two academic years of residence at the Naval Postgraduate School are normally required. With the approval of the Academic Council, this residence requirement may be reduced to not less than one academic year in the case of particular students who have had sufficient prior preparation at other institutions.

3. The general requirements for the Bachelor of Science Degree are as follows:

a. 200 term hours of which at least 80 term hours must be at an upper division level.
b. Mathematics through Calculus.
c. 16 term hours of general physics.
d. 10 term hours of general chemistry.
e. 25 term hours of upper division engineering and/or physics.
f. 35 term hours of upper division work in a major field of study.
g. 36 term hours in Humanities and the Social Sciences.

4. The general requirements for the Bachelor of Science Degree in a specified field are as follows:

a. 216 term hours.
b. 36 term hours in Mathematics and the Physical Sciences.
c. 36 term hours in Humanities and the Social Sciences.
d. Departmental requirements for award of degree in the specified field.

5. The general requirements for the Bachelor of Arts Degree are as follows:

a. 200 term hours of which at least 80 term hours must be at an upper division level.
b. 36 term hours in Mathematics and the Physical Sciences.
c. 36 term hours in Humanities and the Social Sciences.
d. 35 term hours of upper division work in a major field of study.

6. To be eligible for the degree, the student must attain a minimum average quality point rating of 1.0 in all courses of his curriculum. In very exceptional cases, small deficiences from this figure may be waived at the discretion of the Academic Council.

7. With due regard for the above requirement, the Academic Council will decide whether or not to recommend the candidate to the Superintendent of the Naval Postgraduate School for the award of the Bachelor's Degree.

REQUIREMENTS FOR THE MASTER OF SCIENCE DEGREE

1. The Master's Degree may be awarded for successful completion of a curriculum which has the approval of the Academic Council as meriting the degree. Such curricula shall conform to current practice in accredited institutions and shall contain a well defined major.

2. General Postgraduate School minimum requirements for the Master of Science Degree are as follows:

a. 48 term hours of graduate (A and B) level courses.
b. A thesis or its equivalent is required.
c. One academic year in residence.
d. Departmental requirements for the degree in a specified subject.

3. Admission to a program leading to the Master of Science degree requires a baccalaureate degree with appropriate undergraduate preparation for the curriculum to be pursued. If a student enters the Postgraduate School with inadequate undergraduate preparation, he will be required to complete the undergraduate prerequisites in addition to the degree requirements.

4. To be eligible for the Master's Degree, the student must attain a minimum average quality point rating of 2.00 in all the A and B level courses in his curriculum and either 1.50 in the remaining courses or 1.75 in all courses of the curriculum. In very exceptional cases, small deficiences from these grade averages may be waived at the discretion of the Academic Council.

REQUIREMENTS FOR THE DOCTOR'S DEGREE

1. The Doctor's Degree in engineering and related fields is awarded as a result of very meritorious and scholarly achievement in a particular field of study which has been approved by the Academic Council as within the purview of the Naval Postgraduate School. A candidate must exhibit faithful and scholarly application to all prescribed courses of study, achieve a high level of scientific advancement and establish his ability for original investigation. He shall further meet the requirements described in the following paragraphs.

2. Any program leading to the Doctor's degree shall require the equivalent of at least three academic years of study beyond the undergraduate level with at least one academic year being spent at the Naval Postgraduate School.

3. A student seeking to become a candidate for the Doctorate shall hold a Bachelor's degree from a college or university, based on a curriculum that included the prerequisite for full gradnate status in the department of his major study, or he shall have pursued successfully an equivalent course of study. The student shall submit his previous record to the Chairman of the Department of his proposed major subject for determination of his acceptability as a Doctoral student.

4. This Chairman will select two or more additional departments and in consultation with the Chairman of these departments will nominate a Doctoral Committee for the student. The Committee shall consist of five or more members with at least one representative from each of the selected departments. The Chairman of the Department of the major will submit the proposed Committee to the Academic Council for its approval.

5. The Doctoral Committee has full responsibility for prescribing a program of study, which shall include one or more minor fields, suitable to the needs of the student and the requirements for award of the Doctorate.

6. When the program of study in his major and minor fields is essentially complete, the student shall be given qualifying examinations, including tests of his reading knowledge of foreign languages. The selection of these languages depends on the field of study. The minimum is a reading knowledge of German or Russian and a second language selected by his Committee. The language examinations will be conducted by a committee especially appointed by the Academic Council. The other qualifying examinations will cover the major and minor fields of study; they will be both written and oral and will be conducted by the Doctoral Committee. The members of the Academic Council or their delegates will be invited to attend the oral examinations.

7. If the Doctoral Committee decides that the student has successfully completed the qualifying examination, it will report this fact to the Academic Council; the student will then be considered to be a candidate for the Doctorate.

8. The distinct requirement of the Doctorate is successful completion of a scholarly investigation leading to an original and significant contribution to knowledge in the candidate's major area of study. The subject of the investigation must be approved, in advance, by the Doctoral Committee. When the results of the investigation, in the form of a dissertation, are submitted, the Committee will appoint two or more referees who will make individual written reports on the dissertation. The Committee will make the final decision on the acceptance of the dissertation.

9. After the approval of the dissertation, and not later than two weeks prior to the award of the degree, the Committee will conduct a final oral examination of the candidate. The members of the Academic Council or their delegates will be invited to attend the examination. In this final examination, the candidate will be asked to defend his Dissertation and in addition shall be questioned on any subject deemed important to the Committee. Upon completion of the final examination the Committee will nominate the successful candidate to the Academic Council for the award of the Doctor's Degree. The Committee will supply to the Council such information concerning the candidate as may be requested by the Council Secretary.

10. With due regard for all the requirements for awarding the Doctorate and the recommendations of the Doctoral Committee, the Academic Council will make the final decision to recommend the candidate to the Superintendent of the Naval Postgraduate School for the award of the degree.

The Auditorium, King Hall showing Spanagel in the background

THE LIBRARIES

DESCRIPTION

The Library system serves the research and instructional needs of the community comprising students, faculty, and staff of all departments of the School. It embraces an active collection of 114,000 books, 220,000 technical documents, over 2400 periodical works currently received, and 140,000 abstract cards and microcards. These materials parallel the School's curricular fields of engineering, physical sciences, industrial engineering, management, naval sciences, government and the humanities.

The Reference Library, located at the southeast end of Root Hall, provides the open literature sources such as books, periodicals and journals, indexes and abstracting services, pamphlet materials and newspapers. It also furnishes facilities for microfilming and microfilm reading, for photographic and contact reproduction of printed matter, and for borrowing, from other libraries, publications not held in its collections.

The Technical Reports and Classified Materials Section is the principal repository for technical research documents received by the School. It houses 220,000 documents, 68,000 of which are classified, and exercises control over the microcard collection. A machine information storage and retrieval system that utilizes the School's computer facilities is now available for literature searches of documents received since November, 1960.

The Christopher Buckley, Jr., Library is a branch of the Reference Library and is located on the first floor adjacent to the lobby. It is a collection of some 8,000 volumes pertaining principally to naval history and the sea. The establishment of this collection was made possible by the interest and generosity of Mr. Christopher Buckley, Pebble Beach, California, who has been donating books to the School for this Library since 1949.

Reference Room, Postgraduate School Library

STAFF

George R. Luckett, Professor and Librarian (1950); B.S., Johns Hopkins University, 1949; M.S., Catholic University, 1951.

Paul Spinks, Associate Professor and Associate Librarian (1959); B.A., University of Oklahoma, 1958; M.S., University of Oklahoma, 1959.

Edgar R. Larson, Assistant Professor and Reader Services Librarian (1959); B.A., University of Washington, 1939; B.S., University of Washington, 1950.

Janusz I. Kodrebski, Assistant Professor and Head Cataloger (1956); Officer's Diploma, National War College, Warsaw, Poland, 1938; M.S., University of Southern California, 1955.

Janusz Tyszkiewicz-Lacki, Assistant Professor and Technical Reports Librarian (1961); Absolutorium, University of Poznan, Poland, 1924; M.S., University of California, Berkeley, 1958.

Georgia P. Lyke, Reference Librarian (1952); A.A., Hartnell College, 1940.

Mabel Van Vorhis, Librarian, Physical Sciences and Engineering (1955); B.A., University of California, Berkeley, 1926.

Robert Moran Tierney, Acquisitions Librarian (1957); B.A., Columbia University, 1937; M.A., San Jose State College, 1962.

Alice M. Stude, Cataloger (1957); B.S., University of Minnesota, 1930; M.S., University of California, Berkeley, 1961.

Elsa M. Kuswalt, Cataloger (1958); B.A., University of California, Berkeley, 1957.

Doris Baron, Librarian, Physical Sciences and Engineering (1961); B.A., University of California, Berkeley, 1946; M.S., University of Southern California, Los Angeles, 1960.

Roderick R. Hardies, Librarian, Physical Sciences and Engineering (1964); B.A., University of Washington, 1940; M.A., Columbia University, 1952; M.Lib., University of Washington, 1956.

Beth Peterson, Cataloger (1958); A.A., Red Oak College, 1938.

Interior of the Catholic Chapel, Powers Hall

LABORATORY FACILITIES

Extensive laboratory experimentation is carried on in connection with the instructional and research programs of the various departments. The experimental facilities have been greatly improved and expanded in recent years, and further improvement is planned for the future.

The PHYSICS LABORATORIES are equipped to carry on instructional and research work in nuclear physics, low temperature and solid state physics, plasma physics, spectroscopy, and acoustics.

The laboratory facilities include a nuclear physics laboratory centering around a two million volt Van de Graaff accelerator and an Aerojet Nucleonics nuclear reactor operating at power levels up to 1000 watts. In low temperature and solid state physics the equipment includes nitrogen liquifiers, a Collins helium liquifier, He^3 refrigeration equipment to reach temperatures below 1°K, a 12 inch uniform-field electromagnet, microwave gear for spin resonance and maser studies, and high frequency pulse acoustic equipment for phonon studies. The plasma physics equipment includes a number of small vacuum systems, a large plasma system, and diagnostic equipment for studies of plasma dynamics. A steady state plasma source with magnetic fields up to 10,000 gauss will soon be available for plasma research. The spectroscopy equipment includes a large grating spectrograph, a large prism spectrograph, and an infrared spectrophotometer. The acoustics laboratory equipment includes a large anechoic chamber, a small reverberation chamber, and a multiple-unit acoustics laboratory for student experimentation in airborne acoustics. Sonar equipment, test tanks, and instrumentation for investigation in underwater sound comprise the sonar laboratory.

The AERONAUTICAL LABORATORIES contain facilities for experimentation and research in aerodynamics, structural and stress analysis, aerothermodynamics, rocket and jet propulsion, and turbomachinery.

The Subsonic Aerodynamics Laboratory consists of two subsonic wind tunnels, one with a 32x45 inch test section and a speed range up to 185 knots, and the other with a 42x60 inch test section and a speed range up to 200 knots. Force and moment beam balances measure aerodynamic reactions. A small classroom wind tunnel, 7x10 inches in cross-section, and a small two-dimensional smoke tunnel are also in use. Equipment for operating powered propeller aircraft models is available. Experiments in boundary layers, pressure distribution, component aerodynamics, performance and dynamics can be performed.

The Structural Test Laboratory contains testing machines with varying capacities up to 600,000 pounds for demonstration and analysis of relatively small structures. Large aircraft components such as a P2V wing, a F8U-3 wing, and an A3D tail are accommodated on the loading floor of the laboratory where static vibration tests are carried out.

The Dynamics Test Laboratory uses a 20 amplifier analog computer, two electromagnetic shakers, and associated electronic instrumentation for demonstrations of the principles of structural dynamics.

The facilities of the Compressibility Laboratory include a transonic wind tunnel having a 4″x16″ test section and operating in the Mach number range from 0.4 to 1.4; a supersonic wind tunnel having a 4″x4″ test section and a vertical free-jet of 1″x1″ cross-section, both operating in the Mach number range from 1.4 to 4; and a 4″x16″ shock tube. Instruments associated with these facilities include a 9″ and 6″ Mach-Zehnder interferometers and a 9″ and 5″ Schlieren systems for flow observations.

The Rocket and Jet Engine Laboratory facilities provide for full scale operation of current and future Naval aircraft jet engines, and for small rocket engines of 2,000 pounds thrust or less. Two separate and complete test cells are provided in one building for the operations of a J57 engine with afterburner and for the future installation of a T56 turboprop engine. A separate engine maintenance shop is located adjacent to these test cells. A separately located external pad and control house are also in use for the operation of a J34 jet engine and a Boeing XT-50 turboprop engine. Rocket engine tests can be run from a common control room in three test cells housed in the rocket engine building, which also contains a propellant chemistry laboratory. The three test cells provide for operation of solid rocket engines, liquid rocket engines, and hybrid or experimental engines.

The advanced facilities of the Cascade and Turbomachinery Laboratories are distributed in three buildings one of which provides low speed tests with rectilinear, cylindrical and rotating cascades of large dimensions. The source of air is a 700 HP fan, used either to draw or to blow air through the test items. The fan delivers about 100,000 cfm of air at a pressure difference of about 40 inches of water. The fan can be run at speeds of 50% and 75% of the design speed. This source can be used also to perform model tests with flow channels, inlet and discharge casings, scrolls and diffusors. The special rectilinear cascade test rig is equipped with semi-automatic instrumentation; data are obtained with an electronic logging system for data reduction on digital computers. A second building houses a centrifugal compressor test rig, instrumented for conventional performance measurements and for special investigations of three-dimensional flows about both the stationary and the rotating vanes. The third building is devoted to high speed tests, in three tests cells, monitored from a central control room. A 1250 HP variable-speed axial-flow compressor, which is instrumented also for interstage measurements, produces high pressure air either for turbine testing, or to drive test compressors, pumps, and other test items. The compressor is capable of delivering 10,000 cfm of air at sea-level conditions. The design pressure ratio is three, and speed control is possible between 40% and 100% of design speed by means of a hydraulic drive. A surge-suppressing device make is possible to operate test items with greatly varying flow rates. Data acquisition is carried out with an electronic logging system as well as with conventional instrumentation. Adjacent to the third building is a hotspin test unit, where disks and propellers can be rotated at speeds up to 50,000 rpm. Heating and cooling

elements make it possible to impose radial temperature gradients. Instrumentation is provided to conduct stress work, with strain gauges, up to 27,000 rpm and at maximum temperatures of 1800°F.

The CHEMICAL LABORATORIES of the Department of Material Science and Chemistry are well equipped for instructional purposes at both the undergraduate and graduate level in chemistry and chemical engineering. The laboratories include a radio-chemistry ("hot") laboratory with Geiger and scintillation counters and special apparatus for handling and testing radio-active materials; a well-equipped fuel and lubricant laboratory; a plastics laboratory and shop where plastics are synthesized, molded in compression or injection presses, and their mechanical, physical and chemical properties determined; an explosives laboratory with impact tester, ballistics mortar, chronograph and other apparatus for evaluating explosives. Space is also available for faculty and student research projects.

The METALLURGY LABORATORIES are completely equipped with the standard mechanical testing machines and heat-treating furnaces. The latest type of microscopes and metallographs are available for metallographic examination. Facilities for the study of crystal structures include X-ray diffraction units, powder cameras and heating cameras, Weissenberg X-ray goniometers and a recording photo densitometer. Metal fabricating and melting equipment includes a swaging machine, rolling mill, induction and vacuum melting furnaces, a die-casting machine and a welding laboratory. Studies of the effect of high and low temperatures on metals are made in a laboratory equipped with creep testing apparatus and facilities for obtaining low temperatures.

The ELECTRICAL ENGINEERING LABORATORIES, separately housed in a modern two-story building designed for the purpose, have facilities for instruction and research in feedback control systems, electronics, electrical machinery, circuits and measurements. The building and the equipment are arranged for the most effective utilization by students and faculty. Ample equipment is available so that each student may take an active part in the laboratory work.

In addition to the conventional instructional type equipment, the laboratories provide many items of a specialized nature suitable for research projects. Items of special interest in this category include precision primary and secondary standard instruments, a five unit harmonic generating set, a generalized machine laboratory set, a high voltage test set and Schering bridge, a large electronic analog computer with thirty amplifiers and associated function generators and readout equipment, eight Donner analog computers, X-Y recorders, servo analyzers including oscilloscopes with attached Polaroid-Land cameras, an Esiac computer for algebraic functions of a complex variable, Tektronix transistor curve tracer, magnetic amplifiers, wave analyzers, special bridges and electromechanical oscillographs.

The Machine Laboratory has many motors and motor-generator sets with control and measurement benches. Dynamometer sets permit control system study and analysis. The harmonic generator is available for magnetic material studies at higher power frequencies. The generalized machine set permits a quantitative study of basic electromagnetic phenomena. Machine design calculations may be verified by measurements of the characteristics of laboratory equipment.

The Servomechanisms Laboratory is completely equipped with analyzers, Brush recorders, oscilloscopes and cameras, and the basic units required to synthesize and test a wide variety of systems. The computers serve an important part in the synthesis and analysis of control systems.

The Computer Laboratory, used in conjunction with the work of the other laboratories, has ten electronic analog computers and accessories. The equipment is used to solve and analyze many electrical circuits and control system problems. In addition the electronics control and measurement laboratory has many devices, used in modern control systems, and magnetic amplifiers with their accessory equipment.

A well equipped standards and calibration laboratory is used for precision measurements and to calibrate the laboratory instruments used for instruction and research. Photographic records of test results are obtained from electromagnetic oscillographs, oscilloscope cameras, and Polariod-Land cameras. The film is processed in a completely outfitted dark room. Brush recorders are used extensively to obtain test results in graphic form. A number of research rooms are assigned to students and faculty for the study of special projects and research.

The ELECTRONICS LABORATORIES are equipped for carrying on programs of extensive study and research in all branches of the electronics field, and constructing special electronic equipment as may be needed. Facilities are available for investigating the operational characteristics of radio and electronic circuits and equipments at frequencies ranging from d-c to the microwave region. For precision measurements and accurate calibration of instruments, there are standard frequency sources and standardizing equipment.

To illustrate modern communications practices, the laboratories are furnished with representative systems covering a wide range of operating frequencies, power outputs and methods of modulation. These include systems for transmitting manual and automatic telegraphy, voice and video signals.

Improved facilities are now provided for the study of telemetering systems, computing systems, modern radar systems, antenna radiation characteristics, microwave phenomena, and transistors as well as for advanced work in circuit measurements. Additional space is also available for conducting individual research and project work.

The MECHANICAL ENGINEERING LABORATORIES provide facilities for instruction and research in elastic-body mechanisms and dynamics, in hydromechanics and in heat-power and related fields. Noteworthy equipment in the heat-power laboratories includes a gas or oil-fired boiler, 200 psi, and 8000 lb/hr, full automatic controls; a 175 HP gas turbine installation, dynamometer loaded; a two dimensional supersonic air nozzle with Schlieren equipment for analysis of shock-wise flows; a two-stage axial flow test

compressor; a packaged steam power plant; an experimental single cylinder diesel engine; and a CFR diesel fuel test engine. Facilities of the mechanics laboratories include a universal fatigue tester, for testing in tension, compression, bending or torsion, a Chapman polariscope for stress determination by photoelastic method; vibration inducer units and associated equipment for inducing vibrations in mechanical systems with controlled amplitudes and frequencies from 20 to 20,000 cycles per second; dynamic balancing machines; and a linear accelerometer and calibrator unit. Facilities are available for electronic analog simulation of engineering problems.

The FACILITIES IN METEOROLOGY AND OCEANOGRAPHY include all instruments in present-day use for measuring the current physical and dynamic state of the atmosphere, as well as teletype and facsimile communications equipment for the rapid reception and dissemination of weather data in coded and analyzed form for the entire northern hemisphere.

The instruments for gathering weather data include rawinsonde equipment, which provides a continuous recording of temperature, pressure, humidity and wind direction and velocities at designated levels above the surface; radiosonde equipment whereby pressure, temperature and humidity information is transmitted to ground via radio signals from heights that may extend above 100,000 feet; a wiresonde that measures air temperature and humidity conditions in the lower strata of the atmosphere, an inversion meter designed for remote recordings of free air temperature at designated heights in the boundary layer.

The school has recently acquired a 63-foot boat converted for use in Oceanographic Instruction and Research. It is utilized for actual field oceanographic studies by Environmental Science Students. Included in its installed equipment are deep and shallow echo sounders, a bathythermograph winch, and a deep sea hydrographic winch using 20,000 feet of wire.

Oceanographic equipment installed in the area near the school include a wave gauge and a tide gauge for recording nearshore wave action and local tide fluctuations.

Laboratory equipment for MATHEMATICS now available includes an electronic and analogue computer and a digital differential analyzer both of which are used to find the solutions of differential equations; a specially modified accounting machine used in finite differences computations, a variety of planimeter type instruments including a large precision moment integrator, a Stieltjes integrator and a harmonic analyzer. A large number of modern electric desk calculators are available in the laboratory for numerical methods and statistics. Many special models and demonstrators, including the only two automatic relay controlled Wald Sequential Sampling Machines ever made, and other devices and visual aids in mathematics, probability and mechanics are used in support of courses in these subjects. An 85 foot Foucault Pendulum with an 184 lb. bob is kept in constant operation and display.

The COMPUTER FACILITY provides a variety of services to the school. Its primary function is to support the academic programs, serving as a laboratory adjunct to courses on computer programming, logical design and the use of computers in solving scientific and engineering problems as well as those of interest specifically to the Navy. The Facility has a small permanent staff of programmer/mathematicians who provide a consulting service to students and faculty in programming and problem formulation. In addition, their efforts are concentrated toward developing and maintaining a good library of programs and subroutines, improving programming systems and, generally, creating a suitable environment for class and research use of computers. Current Facility activity includes work in the areas of scientific and engineering computing systems programming, information retrieval, simulation, command and control, and student administration.

The School owns the following digital computers: a Control Data Corporation (CDC) 1604, 2 CDC 160's and an IBM 1401. Both CDC 160 Computers are connected to the CDC 1604 in a satellite mode, thus providing a moderately complex computer system with which to study and develop experience in machine-machine interactions such as encountered in operational units in the Navy.

The REACTOR LABORATORY features an AGN-201 reactor which has been recently modified to operate at powers up to 1000 watts. The Laboratory provides facilities and equipment for teaching and research in nuclear physics, radio-chemistry, and reactor physics.

LECTURE SERIES

During the third and fourth terms, the eighth period on Wednesdays is scheduled for presentation of a lecture series in King Hall for all students, sponsored by the Director of Programs.

It is the purpose of this series to present eminently qualified speakers to talk on international affairs and naval professional and technical subjects, to inform as well as to challenge the thinking of the officer students in areas outside of their immediate academic pursuits.

Main Entrance, Herrmann Hall

CURRICULAR OFFICES and PROGRAMS

CURRICULA AT THE POSTGRADUATE SCHOOL

Curriculum	*Curriculum Number*	*Length*	*Academic Associate or Counselor*
Advanced Science			
Chemistry	380	3 yrs.	Prof. Schultz
Hydrodynamics	380	3 yrs.	Prof. Pucci
Mathematics (Applied)	380	3 yrs.	Prof. Pulliam
Material Science	380	3 yrs.	Prof. Buerger
Physics (General)	380	3 yrs.	Prof. Oleson
Physics (Nuclear)	380	3 yr.s	Prof. Oleson
Aeronautical Engineering			
General	610	2 yrs.	Prof. Andrews
Advanced*	610	3 yrs.	Prof. Andrews
Electronics and Communications Engineering			
Communications Engineering			
Basic	600	2 yrs.	Prof. Ward
Advanced	600	3 yrs.	Prof. Ward
Engineering Electronics			
Basic	590	2 yrs.	Prof. Ward
Advanced	590	3 yrs.	Prof. Ward
Information and Control	590	3 yrs.	Prof. Ward
Underwater Acoustics	590	3 yrs.	Prof. Ward
Special (CEC)	472	12-18 mos.	Prof. Ward
Engineering Science	460	1 yr.	Prof. Olsen
Environmental Sciences			
Advanced Meteorology	372	2 yrs.	Prof. Taylor
Advanced Air-Ocean Environment	372	2 yrs.	Prof. Taylor
Oceanography	372	2 yrs.	Prof. Taylor
General Air-Ocean Environment	372	2 yrs.	Prof. Taylor
General Line and Baccalaureate			
General Line		1 yr.	Prof. Houston
Bachelor of Science	461	2 yrs.	Prof. Houston
Bachelor of Arts	461	2 yrs.	Prof. Houston
Naval Engineering			
Naval Engineering (Mechanical)	570	2 yrs.	Prof. Pucci
Naval Engineering (Electrical)	570	2 yrs.	Prof. Pucci
Mechanical Engineering (Advanced)	570	3 yrs.	Prof. Pucci
Electrical Engineering (Advanced)	570	3 yrs.	Prof. Pucci
Navy Management and Operations Analysis			
Naval Management	817	1 yr.	Prof. Peterson
Management (Data Processing)	367	1 yr.	Prof. Williams
Operations Analysis	360	2 yrs.	Prof. Cunningham
Ordnance Engineering			
Nuclear Engineering (Effects)	521	2 yrs.	Prof. Handler
Weapons Systems Engineering			
(General)	530	2 yrs.	Prof. Handler
(Chemistry)	530	3 yrs.	Prof. Handler
(Materials)	530	3 yrs.	Prof. Handler
(Air/Space Physics)	530	3 yrs.	Prof. Handler
(Underwater Physics)	530	3 yrs.	Prof. Handler
(Electronics)	530	3 yrs.	Prof. Handler
(Special)	530	2 yrs.	Prof. Handler

*Usually the third year is taken at a civilian university.

ADVANCED SCIENCE PROGRAMS CURRICULUM NUMBER 380

Chemistry
Hydrodynamics
Material Science
General Physics
Nuclear Physics
Applied Mathematics

Objective—To prepare selected officer personnel to deal with the problem of fundamental and applied research in the fields of general physics, nuclear physics, hydrodynamics, chemistry, material science, and applied mathematics.

Description—Officers nominated for Advanced Science Curricula are selected from among those first-year students enrolled in technical curricula at the Postgraduate School who apply for the Advanced Science Program. Applicants are carefully screened and only those having a very good academic background and who appear to have an excellent chance of succeeding in their chosen field are nominated to the Chief of Naval Personnel.

Officers selected for Advanced Science Curricula complete their first year at the Postgraduate School and normally spend their second and third years of study at a selected civilian university. They may spend the summer prior to entering civilian universities on duty at the Office of Naval Research, Washington, D.C., or at one of the field offices, familiarizing themselves with the work of the Office of Naval Research in the basic sciences, or they may utilize the summer in preparing themselves for graduate school language requirements.

The curriculum at the civilian university for each officer is arranged from courses selected to suit the needs of the Navy, to develop the capabilities of the individual student and to meet the ultimate objective of his specialty.

The Advanced Science Curricula normally lead to the Master of Science degree for those officers meeting the requirements of the civilian universities for that degree and may, in exceptional cases for especially qualified officers, lead to a Doctor's degree.

AERONAUTICAL ENGINEERING PROGRAMS CURRICULUM NUMBER 610

Melvin Edward Hirschi, Commander, U.S. Navy; Curricular Officer; Naval War College, 1955; B.S., Univ. of New Mexico, 1958.

Lawrence Cleveland Chambers, Lieutenant Commander, U.S. Navy; Assistant Curricular Officer; B.S., USNA, 1952; B.S. Aero. Eng., USNPGS, 1959; M.S., Aero. Eng., Stanford Univ., 1960.

Objective—To provide officers with advanced aeronautical education to meet Navy technical requirements in flight vehicles and their environmental fields. Curricula are edited to suit the field of the major, choosing fundamental or advanced material from mathematics, mechanics, physics, chemistry, metallurgy, structural analysis, aerodynamics, propulsion, electricity, electronics, environmental and vehicle dynamics; also the application of these sciences to flight vehicles and to space technology.

Description—The entrance requirement to the Aeronautical Engineering curricula, General and Graduate, is a Bachelor of Science degree, Naval Academy or its equivalent. The Naval Academy coverage in the basic prerequisite sciences in semester hours is Mathematics (20), Basic Engineering (30), Electrical Engineering (14), Physics (10) and Chemistry (8).

First year courses of study are listed below in a sequence of academic terms following entrance, and include the refresher material usually required, commensurate with the time elapsed from previous academic experience for the majority of officer students. Since students may enter school either in August or in January, the same course sequences are usually offered beginning twice a year and running two calendar terms apart. Considerable flexibility in curricular programming is thereby provided, since one or more of the several course sequences can be delayed or accelerated to four terms according to the needs or the validated advanced standing of each student.

When the first-year curriculum has been essentially completed, students may be nominated for candidacy in one of the graduate curricular options: aerospace dynamics, flight structures, propulsion, or avionics. Special programs can also be arranged in other options. Courses to suit the option may be selected from among the second-year courses listed below. Students who continue high scholastic achievement may be admitted to a third year either at this School or at one of the civilian institutions listed. Either the Master or the Engineering Degree may be earned in these curricula. The requirements of the Department of Aeronautics for these degrees are listed on page 62.

Students who do not enter candidacy for a graduate curriculum may continue in one of the second-year options listed, including the flight performance option, leading to the B.S. (A.E) Degree.

First Year

Courses to be selected from the following listing depending upon the student's academic background. Normal academic load 16-18 credit hours.

First Term

Ae 104C	Aerodynamics	3- 2
Ae 204C	Structural Mechanics I	3- 2
Ae 404C	Thermodynamics I	3- 2
Ma 120C	Vectors and Matrices	3- 2
Ma 230D	Calculus of Several Variables	4- 0

Second Term

Ae 105C	Aircraft Performance	3- 2
Ae 109C	Aerodynamics Laboratory	0- 3
Ae 205C	Structural Mechanics II	3- 2
Ae 405C	Thermodynamics II	3- 2
Ma 241C	Elementary Differential Equations	3- 0
Ma 260C	Vector Analysis	3- 0
Ae 001E	Aeronautical Lecture Series	0- 1

Third Term

Ae 106C	Aircraft Dynamics I	3- 2
Ae 206C	Structural Components I	3- 2
Ae 209C	Structural Laboratory	0- 3
Ae 304C	Flight Kinematics	2- 2
Ae 406C	Thermodynamics III	3- 2
EE 105C	Basic Electrical Phenomena	3- 2
LP 101E	Lecture Program I	0- 1

Fourth Term

Ae 107B	Aircraft Dynamics II	3- 2
Ae 207C	Structural Components II	3- 2
Ae 305C	Flight Dynamics I	2- 2
Ae 309C	Dynamics Laboratory	0- 3
Ae 407B	Aircraft Propulsion	3- 2
EE 106C	Basic Circuit Analysis I	3- 2
LP 102E	Lecture Program II	0- 1

Second Year

AEROSPACE DYNAMICS; FLIGHT STRUCTURES; PROPULSION
(Groups AA, AS, AP)

Courses to be selected from the following listing to suit the option.

First Term

Ae 108B	Aircraft Dynamics III	3- 2
Ae 214A	Structural Components III	4- 0
Ae 231B	Structural Design I	2- 2
Ae 306C	Flight Dynamics II	2- 2
Ae 409C	Aerothermodynamics Laboratory	0- 3
Ma 421C	Introduction to Digital Computers	4- 1
Mt 201C	Engineering Materials I	3- 2

Second Term

Ae 221B	Structural Performance	2- 2
Ae 232B	Structural Design II	2- 2
Ae 307B	Flight Dynamics III	2- 2
Ae 408A	Aircraft Propulsion II	3- 2
Ae 511A	Vector Mechanics of Fluid Flow	4- 0
Mt 208B	Properties of Materials	3- 2
Ae 001E	Aeronautical Lecture Series	0- 1

Third Term

Ae 512A	Laminar and Turbulent Flow	4- 0
Ae 601A	Methods in Elasticity	4- 0
Ae 701A	Flight Systems Engineering I	3- 3
EC 105C	Aeromaterials	3- 2
EE 231C	Electronics I	4- 3
Ma 248B	Differential Equations for Optimum Control	3- 0
LP 101E	Lecture Program I	0- 1

Fourth Term

Ae 431A	Aerothermodynamics of Turbomachines I	4- 0
Ae 451A	Propulsion Laboratory II	0- 3
Ae 602A	Static Aeroelasticity	3- 0
Ae 702A	Flight Systems Engineering II	3- 2
EC 112A	Fuels, Combustion, High Temperature Thermodynamics	3- 2
EE 498B	Dynamics of Linear Systems	3- 4
Mc 311C	Vibrations	3- 2
LP 102E	Lecture Program II	0- 1

Second Year

AVIONICS
(Group AV)

Courses to be selected from the following listing:

First Term

Ae 108B	Aircraft Dynamics III	3- 2
Ae 231B	Structural Design I	2- 2
Ae 409C	Aerothermodynamics Laboratory	0- 3
EE 107C	Basic Circuit Analysis II	3- 2
EE 321C	Electromechanical Devices	3- 4

Second Term

Ae 221B	Structural Performance	2- 2
Ae 232B	Structural Design II	2- 2
Ae 408A	Aircraft Propulsion II	3- 2
Ae 511A	Vector Mechanics of Fluid Flow	4- 0
EE 113B	Linear Systems Analysis	4- 3
EE 221C	General Electronics I	3- 3
Ae 001E	Aeronautical Lecture Series	0- 1

Third Term

Ae 215A	Advanced Structures	4- 0
Ae 512A	Laminar and Turbulent Flow	4- 0
Ae 601A	Methods in Elasticity	4- 0
Ae 701A	Flight Systems Engineering I	3- 3
EE 222C	General Electronics II	3- 3
EE 411B	Feedback Control Systems I	3- 3
LP 101E	Lecture Program I	0- 1

Fourth Term

Ae 513A	Compressible Flow I	4- 0
Ae 602A	Static Aeroelasticity	3- 0
Ae 702A	Flight Systems Engineering II	3- 2
EE 223B	Electronic Control and Measurements	3- 3
EE 412A	Feedback Control Systems II	3- 4
Mc 403B	Kinematics of Guidance	3- 0
LP 102E	Lecture Program II	0- 1

Second Year

FLIGHT PERFORMANCE (Group AF)

Courses to be selected from the following listing:

First Term

Ae 108B	Aircraft Dynamics III	3- 2
Ae 151C	Flight Test Evaluation I	2- 0
Ae 161C	Flight Test Evaluation Laboratory I	0- 4
Ae 214A	Structural Components III	4- 0
Ae 231B	Structural Design I	2- 2
Ae 409C	Aerothermodynamics Laboratory	0- 3
Ma 421C	Introduction to Digital Computers	4- 1

Second Term

Ae 152B	Flight Test Evaluation II	2- 0
Ae 162B	Flight Test Evaluation Laboratory	0- 4
Ae 221B	Structural Performance	2- 2
Ae 232B	Structural Design II	2- 2
Ae 408B	Aircraft Propulsion II	3- 2
Ae 501A	Hydro-Aero Mechanics I	4- 0
Ae 001E	Aeronautical Lectures	0- 1

Third Term

Ae 502A	Hydro-Aero Mechanics II	4- 0
Ae 701A	Flight Systems Engineering I	3- 3
EE 231C	Electronics I	4- 3
Mt 201C	Introduction to Physical Metallurgy	3- 2
LP 101E	Lecture Program I	0- 1

Fourth Term

Ae 153B	Flight Test Evaluation III	2- 0
Ae 163B	Flight Test Evaluation Laboratory III	0- 4
Ae 430A	Principles of Turbomachines	3- 0
Ae 450A	Propulsion Laboratory I	0- 3
Ae 508A	Compressibility	3- 2
Ae 702A	Flight Systems Engineering II	3- 2
Mt 208B	Properties of Materials	3- 2
LP 102E	Lecture Program II	0- 1

Third Year

ALL OPTIONS

Courses may be selected from the following listing as available, or from advanced courses in mathematics and other subjects.

Ae 010C	Aeronautical Seminar	0- 1
Ae 215A	Advanced Structures	4- 0
Ae 422A	Performance of Propulsion Systems	4- 2
Ae 423A	Advanced Problems in Propulsion	4- 2
Ae 432A	Aerothermodynamics of Turbomachines I	4- 0
Ae 433A	Advanced Propulsion Systems	4- 0
Ae 434A	Space Power Plants	3- 0
Ae 440A	Design of Turbomachinery	4- 0
Ae 452A	Propulsion Laboratory III	0- 3
Ae 453A	Propulsion Laboratory IV	0- 3
Ae 454A	Laboratory Seminar I	1- 4
Ae 460A	Propulsion Design Laboratory	0- 2
Ae 471A	Combustion Thermodynamics	3- 2
Ae 472A	Aerothermochemistry	3- 2
Ae 473A	Advanced Problems in Combustion and/or Aerophysics	3- 2
Ae 474A	Advanced Problems in Combustion and/or Aerophysics	3- 2
Ae 514A	Compressible Flow II	3- 0
Ae 519A	Compressible Flow Laboratory	0- 2
Ae 521A	Magnetoaerodynamics	4- 0
Ae 531A	Conductive and Convective Heat Transfer	4- 0
Ae 532A	Convective and Radiative Heat Transfer	4- 0
Ae 603A	Aeroelasticity (Flutter) and Vibration	4- 0
Ae 604A	Thermoelasticity	3- 1
Ae 605A	Plates and Shells	4- 0
Ae 606A	Matrix Structural Analysis	4- 0
Ae 610A	Aeronautical Structures Seminar	3- 0
Ae 623A	Static and Dynamic Aeroelasticity	4- 0
Ae 633A	Aeroelasticity Laboratory	0- 3
EE 114B	Communication Theory I	4- 0
EE 233B	Communication Circuits and Systems	4- 3
EE 419B	Non-Linear and Sampled Systems	3- 4
EE 422B	Modern Communications	3- 3
EE 631B	Theory of Antennas	3- 3
EE 951A	Thesis Seminar	0- 1
Ma 322A	Decision Theory and Classical Statistics	3- 2

Civilian universities currently used in third year work and the fields in which they provide the strongest competence for advanced study are as follows:

CALIFORNIA INST. OF TECHNOLOGY, PASADENA, CAL.
- Aerodynamics
- Structures
- Jet Propulsion

MASSACHUSETTS INST. OF TECHNOLOGY, CAMBRIDGE, MASS.
- Astronautics
- Airborne Weapons Systems

UNIVERSITY OF MICHIGAN, ANN ARBOR, MICHIGAN
- Aerodynamics
- Aero-instrumentation
- Propulsion
- Structures
- Nuclear Engineering

PRINCETON UNIVERSITY, PRINCETON, N.J.
- Aerodynamics (flight mechanics)
- Propulsion

COLLEGE OF AERONAUTICS, CRANFIELD, ENGLAND
- Aerodynamics
- Aircraft Design
- Propulsion
- Aircraft Electronics

STANFORD UNIVERSITY, STANFORD, CAL.
- Aero- and Gasdynamics
- Structures
- Guidance and Control

ELECTRONICS AND COMMUNICATIONS ENGINEERING PROGRAMS
CURRICULA NUMBERS 600, 590, and 472

ALBERT FRANCIS SHIMMEL, Commander, U.S. Navy; Curricular Officer; B.S., USNA, 1948; Command Communications, USNPGS, 1953.

JOHN RICHARD KING, Lieutenant, U.S. Navy; Assistant Curricular Officer; B.S., Communications Engineering, USNPGS, 1965.

OBJECTIVE—In the Bachelor of Science program to educate officers in the basic scientific and engineering fields related to electronics and communications and their application to the art of naval warfare.

In the Master of Science program to educate a selected group of academically qualified officers to develop a particular competence and ability in directing the development, evaluation and operation of electronics and communications systems, as required by the Navy.

DESCRIPTION—Officers ordered for instruction in Electronics or Communications Engineering normally enter a basic core curriculum for the first year. However, officers with recent and appropriate academic backgrounds may be placed in a correspondingly advanced program. At the end of the first year, officers will be selected either for an advanced 3-year curriculum or for a 2-year curriculum. This selection is based upon the Superintendent's appraisal of the individual's academic ability and is subject to final approval by the Chief of Naval Personnel. For properly qualified entering students, successful completion of one of the two 2-year curricula leads to the award of a Bachelor of Science degree in either Engineering Electronics or Communications Engineering, while successful completion of one of the 3-year curricula leads to the award of a Master of Science degree in one of these two fields.

First Year Curriculum (for BS and MS Programs)

First Term

EE 111C	Fields and Circuits	4- 4
Ma 150C	Vectors and Matrices	4- 1
Ma 230D	Calculus of Several Variables	4- 0
PH 105C	Mechanics	4- 0
		16- 5

Second Term

EE 112C	Circuit Analysis	4- 3
EE 211C	Electron Devices and Circuits I	4- 2
Ma 240C	Elementary Differential Equations	2- 0
Ma 251C	Elementary Infinite Series	3- 0
		13- 5

Third Term

EE 113B	Linear Systems Analysis	4- 3
EE 212C	Electron Devices and Circuits II	4- 3
Ma 271C	Complex Variables	4- 0
PH 205C	Waves and Particles	4- 0
		16- 6

Fourth Term

EE 114B	Communication Theory I	4- 0
EE 213C	Pulse and Wave Forming Circuits	4- 3
*EE 811C	Electronic Computers	3- 3
*PH 604C	Structure of Atoms and Solids	4- 0
		15- 6

Fifth Term (includes leave period)

MN 191C	Organization and Management	4- 0
*MN 210C	Principles of Economics	4- 0
SP 012D	Art of Presentation	2- 0
		10- 0

*Students eligible for the MS curricula will: Replace EE 811C by Ma 245B Partial Differential Equations (3-0); Replace PH 604C by PH 605B Atomic Physics (4-0), and Replace MN 210C by Ma 260C Vector Analysis (3-0).

Second Year Common Curriculum (for BS Programs)

First Term

EE 611C	Electromagnetic Fields	4- 0
EE 214C	Electronic Communication Circuits I	4- 3
EE 116B	Communication Theory II	3- 2
EE 731C	Electronic Measurements	3- 4
		14- 9

Second Term

EE 612C	Transmission of Electromagnetic Energy	3- 2
EE 215C	Electronic Communication Circuits II	4- 3
EE 216C	Special Electronic Devices	4- 2
*EE 812B	Logical Design and Circuitry	4- 0
		15- 7

*Substitution of another elective (with no lab) will normally be permitted. Communications students will normally take MN 412A Managerial Economics (4-0).

Second Year Common Curriculum (for MS Programs)

First Term

EE 621B	Electromagnetics I	3- 2
EE 214C	Electronic Communication Circuits I	4- 3
EE 811C	Electronic Computers	3- 3
Ma 321B	Probability	4- 2
		14-10

Second Term

EE 622B	Electromagnetics II	4- 0
EE 215C	Electronic Communication Circuits II	4- 3
EE 571A	Statistical Communication Theory	3- 2
PH 705B	Solid State Physics	4- 2
		15- 7

Third Term

EE 217B	Advanced Electron Devices	4- 2
EE 321C	Electromechanical Devices	3- 4
Ma 322A	Decision Theory & Classical Statistics	3- 2
*EE 433A	Radar Systems	4- 2
		14-10

*Underwater Acoustics students will substitute PH 431B Fundamental Acoustics (4-0) and Communications students will substitute EE 671B Theory of Propagation (4-0).

ENGINEERING ELECTRONICS CURRICULUM NUMBER 590

BS Program

For the last two terms of the second year, students in the 2-year BS program are permitted to elect a number of courses to further their individual interests and Naval experience. Four courses not exceeding 24 total hours or 3 labs per week are required for each term. The choice of elective courses is subject to the approval of the Curricular Officer and Academic Associate.

Third Term

EE 321C	Electromechanical Devices	3- 4
PH 450C	Underwater Acoustics	3- 2
EE 432B	Theory of Radar	3- 3
*EE 671B	Theory of Propagation	4- 0
		13- 9

Fourth Term

EE 411B	Feedback Control Systems I	3- 3
*EE 471B	Guidance and Navigation	3- 0
*EE 254B	Transistor Circuits	3- 3
*EE 455B	Sonar Systems	3- 3
		12- 9

*Typical electives.

MS Program

Students selected for an MS program in Engineering Electronics will continue their studies in one of three options listed below. These options are designated to develop a particular competence in Advanced Electronics, Underwater Acoustics, or Information and Control Systems. The final six terms of these programs are a combination of required and elective courses.

Where elective courses are permitted, the selection must meet the approval of the Curricular Officer and Academic Associate, as being consistent with the option major.

The third term of the third year may be spent in an industrial electronics laboratory. During this period, the student works as a junior engineer on a selected project.

OPTION I—ADVANCED ELECTRONICS (Group EA)

Second Year

Fourth Term

EE 731C	Electronic Measurements	3- 4
EE 411B	Feedback Control Systems I	3- 3
EE 541A	Signal Processing	4- 0
EE 253A	Microwave Tubes	3- 2
		13- 9

Fifth Term (includes leave period)

Field trip, and/or supervised project work, and/or appropriate elective courses. The latter must include MN 210C Principles of Economics (4-0) unless this has already been taken.

Third Year

First Term

*EE 631B	Theory of Antennas	3- 3
EE 121A	Advanced Network Analysis	3- 2
PH 152B	Mechanics II	4- 0
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3
		10- 9

Second Term

*EE 652A	Microwave Circuits & Measurements	3- 2
*EE 473A	Missile Guidance Systems	3- 0
OA 141B	Fundamentals of Operations Research/ Systems Analysis	4- 1
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3
		10- 7

Third Term

Industrial tour, or supervised project work.

Fourth Term

*EE 254B	Transistor Circuits	3- 3
*EE 481B	Electronic Countermeasures	3- 3
*EE 623A	Advanced Electromagnetic Theory	3- 0
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3
		9-10

*Typical electives.

OPTION II—UNDERWATER ACOUSTICS (Group EW)

Second Year

Fourth Term

EE 411B	Feedback Control Systems I	3- 3
EE 541A	Signal Processing	4- 0
PH 432B	Underwater Acoustics	4- 3
OC 110C	Introduction to Oceanography	3- 0
PH 480E	Acoustics Colloquium	0- 1
		14- 7

Fifth Term (includes leave period)

Field trip and/or supervised project work, and/or appropriate elective courses. The latter must include MN 210C Principles of Economics (4-0) unless this has already been taken.

Third Year

First Term

EE 121A	Advanced Network Analysis	3- 2
EE 451A	Sonar Systems Engineering	4- 3
PH 461A	Transducer Theory and Design	3- 3
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3
		10-12

Second Term

*EE 652A	Microwave Circuits & Measurements	3- 2
PH 433A	Propagation of Waves in Fluids	3- 0
OA 141B	Fundamentals of Operations Research/ Systems Analysis	4- 1
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3
		10- 7

Third Term

Industrial tour, or supervised project work.

Fourth Term

*EE 254B	Transistor Circuits	3- 3
*EE 481B	Electronic Countermeasures	3- 3
PH 442A	Finite Amplitude Waves in Fluids	3- 0
EE 951E	Thesis Seminar	0- 1
PH 480E	Acoustics Colloquium	0- 1
	Thesis	0- 3
		9-11

*Typical electives.

OPTION III—INFORMATION AND CONTROL (Group EI)

Second Year

Fourth Term

EE 731C	Electronic Measurements	3- 4
EE 411B	Feedback Control Systems I	3- 3
EE 541A	Signal Processing	4- 0
EE 812B	Logical Design and Circuitry	4- 0
		14- 7

Fifth Term (includes leave period)

Field trip and/or supervised project work, and/or appropriate elective courses. The latter must include MN 210C Principles of Economics (4-0) unless this has already been taken.

Third Year

First Term

EE 121A	Advanced Network Analysis	3- 2
EE 551A	Information Networks	3- 2
Ma 423B	Advanced Digital Computer Programming	4- 0
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3
		10- 8

Second Term

EE 462A	Automation and System Control	3- 3
EE 419B	Nonlinear and Sampled Systems	3- 4
OA 141B	Fundamentals of Operations Research/ Systems Analysis	4- 1
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3
		10-12

Third Term

Industrial tour, or supervised project work.

Fourth Term

*EE 254B	Transistor Circuits	3- 3
*EE 481B	Electronic Countermeasures	3- 3
Ma 116B	Matrices and Numerical Methods	3- 2
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3
		9-12

*Typical electives.

COMMUNICATIONS ENGINEERING CURRICULUM NUMBER 600 (Group CE)

BS Program

For the last two terms of the second year, students in the 2-year BS program are permitted to elect a number of courses. Four courses not exceeding 24 total hours or 3 labs per week are required for each term. The choice of elective courses is subject to the approval of the Curricular Officer and Academic Associate.

Second Year

Third Term

EE 631B	Theory of Antennas	3- 3
EE 422B	Modern Communications	3- 3
EE 321C	Electromechanical Devices	3- 4
*Ma 311C	Introduction to Probability and Statistics	4- 1
		13-11

Fourth Term

EE 671B	Theory of Propagation	4- 0
EE 411B	Feedback Control Systems I	3- 3
*EE 254B	Transistor Circuits	3- 3
*OA 101C	Elements of Operations Research/ Systems Analysis	4- 1
		14- 7

*Typical electives.

MS Program

Communications Engineering students selected for an MS program will follow the curriculum outlined below.

Where elective courses are permitted, the selection must meet the approval of the Curricular Officer and Academic Associate, as being consistent with the major field of study.

The third term of the third year may be spent in an industrial laboratory. During this period, the student works as a junior engineer on a selected project.

Second Year

Fourth Term

EE 731C	Electronic Measurements	3- 4
EE 411B	Feedback Control Systems I	3- 3
EE 541A	Signal Processing	4- 0
EE 422B	Modern Communications	3- 3
		13-10

Fifth Term (includes leave period)

Field trip and/or supervised project work, and/or appropriate elective courses. The latter must include MN 210C Principles of Economics (4-0) unless this has already been taken.

Third Year

First Term

EE 121A	Advanced Network Analysis	3- 2
EE 631B	Theory of Antennas	3- 3
OA 111B	Principles of Operations Research/ Systems Analysis	4- 2
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3
		10-11

Second Term

*EE 652A	Microwave Circuits & Measurements	3- 2
OA 112A	Advanced Methods in Operations Analysis	4- 0
MN 412A	Managerial Economics	4- 0
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3
		11- 6

Third Term

Industrial tour, or supervised project work.

Fourth Term

*EE 254B	Transistor Circuits	3- 3
*EE 821B	Computer Systems Technology	3- 3
*MN 473A	Quantitative Decision Making	3- 0
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3
		9-10

*Typical electives.

SPECIAL ELECTRONICS CURRICULUM FOR SELECTED CEC OFFICERS

CURRICULUM NUMBER 472 (Group EY)

Objective—To prepare selected CEC officers for special duties requiring a technical capability for planning electronic facilities and accomplishing the engineering studies required in the development of plans and specifications for their construction.

Prerequisite—Recent BSEE degree from an accredited institution with an overall grade average of at least B.

Description—For properly qualified entering students, successful completion of this curriculum affords the opportunity to earn a Master of Science degree in Engineering Electronics. The curriculum can be modified both as to length and content depending upon the individual student's background. A typical curriculum is outlined below.

First Year

First Term

EE 113B	Linear Systems Analysis	4- 3
EE 621B	Electromagnetics I	3- 2
EE 811C	Electronic Computers	3- 3

Math review course to suit student's needs.

Second Term

EE 114B	Communication Theory I	4- 0
EE 411B	Feedback Control Systems I	3- 3
EE 622B	Electromagnetics II	4- 0
PH 604C	Structure of Atoms and Solids	4- 0
		15- 3

Third Term

EE 217B	Advanced Electronic Devices	4- 2
EE 121A	Advanced Network Analysis	3- 2
EE 631B	Theory of Antennas	3- 3
Ma 321B	Probability	4- 2
		14- 9

Fourth Term

EE 571A	Statistical Communication Theory	3- 2
EE 422B	Modern Communications	3- 3
EE 253A	Microwave Tubes	3- 2
EE 671B	Theory of Propagation	4- 0
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 2
		13-10

Fifth Term (includes leave period)

Student will work on thesis and participate in CEC workshop seminar.

Second Year

First Term

EE 433A	Radar Systems	4- 2
Ma 322A	Decision Theory & Classical Statistics	3- 2
Elective		
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3

Second Term

EE 541A	Signal Processing	4- 0
OA 141B	Fundamentals of Operations Research/ Systems Analysis	4- 1
Elective		
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 3

ENGINEERING SCIENCE PROGRAMS CURRICULUM NUMBER 460

MARK HOPKINS, JR., Commander, U.S. Navy; Curricular Officer; B.S., USMMA, 1950; M.S., USNPGS, 1958.

OBJECTIVE—To provide post-commissioning education in the fields of Mathematics, Physics and Engineering, designed to update and build on undergraduate education and to prepare students for advanced functional training such as Naval Tactical Data Systems; Polaris and other missiles; instructor duty on school staffs; test pilot schools.

The High and Average Academic Background Curricula may serve as a review to qualify selected officer-students for transfer to other technical curricula. Such transfers normally will be made upon completion of the second term of these curricula and will be based upon length of availability of student for duty under instruction, academic performance and quota limitations in the technical curricula.

HIGH ACADEMIC BACKGROUND (Group SA)

First Term

Ma 071D	Calculus I	5- 0
PH 021C	Mechanics	4- 0
CH 106D	Principles of Chemistry I	3- 2
OC 110C	Introduction to Oceanography	3- 0
		15- 2

Second Term

Ma 072D	Calculus II	5- 0
PH 022C	Fluid Mechanics, Wave Motion and Thermodynamics	4- 0
PH 023C	Electricity and Magnetism	4- 0
CH 107D	Principles of Chemistry II	3- 2
		16- 2

Third Term

Ma 073C	Differential Equations	5- 0
Ma 315C	Introduction to Probability and Statistics	4- 2
PH 024C	Electromagnetic Radiation and Optics	4- 0
EE 271C	Electronic Devices and Circuits I	4- 2
		17- 4

Fourth Term

Ma 416C	Numerical Methods and Fortran Programming	4- 1
PH 025C	Modern Physics	4- 0
OA 141B	Fundamentals of Operations Research/ Systems Analysis	4- 1
EE 272C	Electronic Devices and Circuits II	4- 2
		16- 4

AVERAGE ACADEMIC BACKGROUND (Group SB)

First Term

Ma 051D	Calculus and Analytic Geometry I	5- 0
PH 016D	General Physics—Mechanics	4- 0
CH 106D	Principles of Chemistry I	3- 2
OC 110C	Introduction to Oceanography	3- 0
		15- 2

Second Term

Ma 052D	Calculus and Analytic Geometry II	5- 0
PH 017D	General Physics—Thermodynamics, Sound and Light	4- 0
PH 018D	General Physics—Electricity and Magnetism	4- 0
CH 107D	Principles of Chemistry II	3- 2
		16- 2

Third Term

Ma 053D	Calculus and Analytic Geometry III	5- 0
Ma 315C	Introduction to Probability and Statistics	4- 2
PH 019C	Modern Physics	4- 0
EE 271C	Electronic Devices and Circuits I	4- 2
		17- 4

Fourth Term

Ma 073C	Differential Equations	5- 0
Ma 416C	Numerical Methods and Fortran Programming	4- 1
OA 141B	Fundamentals of Operations Research/ Systems Analysis	4- 1
EE 272C	Electronic Devices and Circuits II	4- 2
		17- 4

FAIR ACADEMIC BACKGROUND (UPPER) (Group SC)

First Term

Ma 031D	College Algebra and Trigonometry	5- 0
PH 001D	General Physics I—Mechanics	4- 0
CH 001D	Introductory General Chemistry I	4- 3
OC 110C	Introduction to Oceanography	3- 0
		16- 3

Second Term

Ma 051D	Calculus and Analytic Geometry I	5- 0
Ma 311C	Introduction to Probability and Statistics	4- 1
PH 003D	General Physics III—Electricity and Magnetism	4- 0
CH 002D	Introductory General Chemistry II	3- 3
		16- 4

Third Term

Ma 052D	Calculus and Analytic Geometry II	5- 0
PH 002D	General Physics II—Harmonic Motion, Sound and Heat	4- 0
OA 101C	Elements of Operations Research/ Systems Analysis	4- 1
EE 271C	Electronic Devices and Circuits I	4- 2
		17- 3

Fourth Term

Ma 053D	Calculus and Analytic Geometry III	5- 0
Ma 411C	Digital Computers and Military Applications	4- 0
PH 004D	General Physics IV—Light and Modern Physics	4- 0
EE 272C	Electronic Devices and Circuits II	4- 2
		17- 2

FAIR ACADEMIC BACKGROUND (LOWER)
(Group SD)

First Term

Ma 025D	Elementary Sets with Applications	3- 0
Ma 030D	Intermediate Algebra	5- 0
PH 001D	General Physics I—Mechanics	4- 0
CH 001D	Introductory General Chemistry I	4- 3
		16- 3

Second Term

Ma 031D	College Algebra and Trigonometry	5- 0
PH 003D	General Physics III—Electricity and Magnetism	4- 0
CH 002D	Introductory General Chemistry II	3- 3
OC 110C	Introduction to Oceanography	3- 0
		15- 3

Third Term

Ma 051D	Calculus and Analytic Geometry I	5- 0
Ma 311C	Introduction to Probability and Statistics	4- 1
PH 002D	General Physics II—Harmonic Motion, Sound and Heat	4- 0
EE 271C	Electronic Devices and Circuits I	4- 2
		17- 3

Fourth Term

Ma 052D	Calculus and Analytic Geometry II	5- 0
Ma 411C	Digital Computers and Military Applications	4- 0
OA 101C	Elements of Operations Research/ Systems Analysis	4- 1
EE 272C	Electronic Devices and Circuits II	4- 2
		17- 3

ENVIRONMENTAL SCIENCES PROGRAMS
CURRICULA NUMBERS 372 AND 440

Julius Frederick Steuckert, Captain, U. S. Navy; Curricular Officer; B.S., USNA, 1940; B.S., Aerological Engineering, USNPGS, 1948.

Samuel Woodworth Selfridge, Jr., Commander, U.S. Navy; Assistant Curricular Officer; B.S., USNA, 1944; M.S., USNPGS, 1960.

METEOROLOGY CURRICULUM
CURRICULUM NUMBER 372
(Group MM)

Objective—To prepare officers to become qualified meteorologists with a working knowledge of Oceanography as applied to naval operations and to enable them, through advanced study, to conduct independent research.

First Year

First Term

Ma 120C	Vectors and Matrices with Geometric Applications	3- 1
Ma 230D	Calculus of Several Variables	4- 0
Mr 200C	Introduction to Meteorology	3- 0
Oc 110C	Introduction to Oceanography	3- 0
Ph 196C	Review of General Physics	4- 2
Mr 001D	Weather Codes and Elementary Analysis	0- 3
		17- 6

Second Term

Ma 240C	Elementary Differential Equations	2- 0
Ma 251C	Elementary Infinite Series	3- 0
Mr 201C	Elementary Weather-Map Analysis	0- 9
Mr 211C	Elementary Weather-Map Analysis	3- 0
Mr 410C	Meteorological Instruments	2- 2
Mr 413B	Thermodynamics of Meteorology	3- 2
		13-13

Third Term

Ma 261B	Vector Mechanics	5- 0
Ma 332B	Statistics I	3- 0
Mr 202C	Weather-Map Analysis	0- 6
Mr 212C	Introduction to Weather Elements	3- 0
Mr 321A	Dynamic Meteorology I	3- 0
Oc 220B	Descriptive Oceanography	3- 0
LP 101E	Lecture Program I	0- 1
		17- 7

Fourth Term

Ma 125B	Numerical Methods for Digital Computers	2- 2
Ma 333B	Statistics II	2- 2
Mr 203C	Forecasting Weather Elements and Mesometeorology	0- 6
Mr 213C	Forecasting Weather Elements and Mesometeorology	2- 0
Mr 322A	Dynamic Meteorology II	3- 0
Oc 260B	Sound in the Ocean	3- 0
LP 102E	Lecture Program II	0- 1
		12-11

Fifth Term

Ma 421C	Introduction to Digital Computers	4- 1
		4- 1

During intersessional period, students are instructed in various aspects of Meteorology and Oceanography as applied to naval operations. Visits to naval and civilian installations are also conducted.

Second Year

First Term

Ma 128B	Numerical Methods in Partial Differential Equations	3- 1
Mr 204B	Upper-Air and Surface Prognosis	0- 6
Mr 214B	Upper-Air and Surface Prognosis	3- 0
Mr 323A	Dynamic Meteorology III	3- 0
Mr 412A	Physical Meteorology	3- 0
Mr 521B	Synoptic Climatology	2- 2
Ma 420E	Computer Operations (five weeks)	1- 1
		15-10

Second Term

Mr 205B	The Middle Atmosphere	0- 6
Mr 215B	The Middle Atmosphere	3- 0
Mr 228B	Tropical and Southern Hemisphere Meteorology	3- 0
Mr 324A	Dynamical Prediction	3- 3
Mr 325A	Energetics of General Circulation	2- 0
		11- 9

Third Term

Mr 208B	Tropical and Southern Hemisphere Meteorology	0- 6
Mr 422A	The Upper Atmosphere	4- 0
Oc 611B	Ocean Wave Forecasting	3- 6
LP 101E	Lecture Program I	0- 1
	Thesis I	0- 8
		7-21

Fourth Term

Mr 206C	Naval Weather Service Operations	1- 9
Oc 619B	Oceanographic Forecasting	3- 4
Mr 810B	Seminar in Meteorology and Oceanography	2- 0
Oc 201B	Ocean Waves and Tides	3- 1
LP 102E	Lecture Program II	0- 1
	Thesis II	0- 8
		9-23

For properly qualified entering students, this curriculum affords the opportunity to qualify for the Master of Science degree in Meteorology.

AIR-OCEAN ENVIRONMENT CURRICULUM

CURRICULUM NUMBER 372
(Group MA)

Objective—To provide education in Oceanography and Meteorology with emphasis on interaction between the atmosphere and oceans. Special naval applications of this curriculum include forecasting weather and sea conditions for submarine operations, antisubmarine warfare, surface shipping and air operations.

First Year

First Term

Ma 051D	Calculus and Analytic Geometry I	5- 0
Mr 200C	Introduction to Meteorology	3- 0
Oc 110C	Introduction to Oceanography	3- 0
Ph 190D	Survey of Physics I	3- 0
Mr 001D	Weather Codes and Elementary Analysis	0- 3
		14- 3

Second Term

Ma 052D	Calculus and Analytic Geometry II	5- 0
Mr 201C	Elementary Weather-May Analysis	0- 9
Mr 211C	Elementary Weather-Map Analysis	3- 0
Mr 410C	Meteorological Instruments	2- 2
Ph 191D	Survey of Physics II	3- 0
		13-11

Third Term

Ma 053D	Calculus and Analytic Geometry III	5- 0
Mr 202C	Weather-Map Analysis	0- 6
Mr 212C	Introduction to Weather Elements	3- 0
Mr 402C	Introduction to Meteorological Thermodynamics	3- 2
Oc 220B	Descriptive Oceanography	3- 0
LP 101E	Lecture Program I	0- 1
		16- 9

Fourth Term

Ma 381C	Elementary Probability and Statistics	4- 2
Mr 203C	Forecasting Weather Elements and Mesometeorology	0- 6
Mr 213C	Forecasting Weather Elements and Mesometeorology	2- 0
Mr 301B	Elementary Dynamic Meteorology I	4- 0
Oc 700B	Oceanographic Instruments and Observations	2- 2
LP 102E	Lecture Program II	0- 1
		12-11

Fifth Term

Ma 412C	Small Scale Digital Computers	3- 2
Oc 720B	Field Experience in Oceanography	0- 4
		3- 6

During intersessional period, students are instructed in various aspects of Meteorology and Oceanography as applied to naval operations. Visits to naval and civilian installations are also conducted.

Second Year

First Term

Mr 403B	Introduction to Micrometeorology	4- 0
Mr 204B	Upper-Air and Surface Prognosis	0- 6
Mr 214B	Upper-Air and Surface Prognosis	3- 0
Mr 302B	Elementary Dynamic Meteorology II	4- 0
Mr 521B	Synoptic Climatology	2- 2
Oc 260B	Sound in the Ocean	3- 0
		16- 8

Second Term

Mr 205B	The Middle Atmosphere	0- 6
Mr 215B	The Middle Atmosphere	3- 0
Mr 228B	Tropical and Southern Hemisphere Meteorology	3- 0
Oc 611B	Ocean Wave Forecasting	3- 6
Oc 201B	Ocean Waves and Tides	3- 1
		12-13

Third Term

Oc 241B	Elementary Dynamic Oceanography	3- 0
Mr 208B	Tropical and Southern Hemisphere Meteorology	0- 6
Oc 615B	Oceanographic Forecasting I	3- 4
LP 101E	Lecture Program I	0- 1
	Research Problem	0- 6
		6-17

Fourth Term

Mr 206C	Naval Weather Service Operations	1- 9
Mr 810B	Seminar in Meteorology and Oceanography	2- 0
Oc 612B	Arctic Oceanography	3- 0
Oc 617B	Oceanographic Forecasting II	3- 4
LP 102E	Lecture Program II	0- 1
		9-14

For properly qualified entering students, this curriculum affords an opportunity to qualify for a Bachelor of Science degree in Meteorology.

OCEANOGRAPHY CURRICULUM

CURRICULUM NUMBER 440 (Group MO)

OBJECTIVE—To provide officers with an education in physical oceanography with particular emphasis on naval operations, and to enable them through advanced study to conduct independent research.

First Year

First Term

Ma 120C	Vectors and Matrices	3- 1
Ma 230D	Calculus of Several Variables	4- 0
Mr 200C	Introduction to Meteorology	3- 0
Oc 110C	Introduction to Oceanography	3- 0
Ph 196C	Review of General Physics	4- 2
Mr 001D	Weather Codes and Elementary Analysis	0- 3
		17- 6

Second Term

Ma 240C	Elementary Differential Equations	2- 0
Ma 251C	Elementary Infinite Series	3- 0
Mr 201C	Elementary Weather-Map Analysis	0- 9
Mr 211C	Elementary Weather-Map Analysis	3- 0
Oc 320B	Introduction to Geological Oceanography	3- 2
Oc 420B	Introduction to Biological Oceanography	3- 2
		14-13

Third Term

Ma 261B	Vector Mechanics	5- 0
Ma 332B	Statistics I	3- 0
Oc 220B	Descriptive Oceanography	3- 0
Mr 410C	Meteorological Instruments	2- 2
Mr 413B	Thermodynamics of Meteorology	3- 2
LP 101E	Lecture Program I	0- 1
		16- 5

Fourth Term

Ma 125B	Numerical Methods for Digital Computers	2- 2
Ma 333B	Statistics II	2- 2
Oc 211A	Ocean Waves	3- 0
Oc 251A	Dynamic Oceanography I	3- 0
Oc 700B	Oceanographic Instruments and Observations	2- 2
LP 102E	Lecture Program II	0- 1
		12- 7

Fifth Term

Ma 421C	Introduction to Digital Computers	4- 1
Oc 720B	Field Experience in Oceanography	0- 4
		4- 5

During intersessional period, students are instructed in various phases of Oceanography as it applies to naval operations. Visits to naval and civilian installations are also conducted.

Second Year

First Term

Ma 128B	Numerical Methods in Partial Differential Equations	3- 1
Oc 212A	Tides and Tidal Currents	3- 0
Oc 611B	Ocean Wave Forecasting	3- 6
Oc 252A	Dynamic Oceanography II	3- 0
Oc 260B	Sound in the Ocean	3- 0
		15- 7

Second Term

Oc 213A	Shallow-Water Oceanography	3- 1
Oc 520B	Introduction to Chemical Oceanography	3- 2
Oc 253A	Dynamic Oceanography III	3- 0
Oc 615B	Oceanographic Forecasting I	3- 4
		12- 7

Third Term

Oc 820A	Special Topics in Oceanography	3- 0
Oc 340A	Marine Geophysics	2- 0
Oc 617B	Oceanographic Forecasting II	3- 4
LP 101E	Lecture Program I	0- 1
	Thesis I	0- 8
		8- 13

Fourth Term

Oc 613B	Arctic Oceanography	3- 4
Oc 810B	Seminar in Oceanography	2- 0
	Elective	3- 0
	Thesis II	0- 8
LP 102E	Lecture Program II	0- 1
		8-13

This curriculum affords the opportunity to qualify for the degree of Master of Science in Oceanography, with a particular capability in physical oceanography. Students entering the curriculum with the baccalaureate in geology, or chemistry may follow a modified curriculum, including preparation of a thesis in geological, biological, or chemical oceanography, which will qualify them for the same degree but with a capability in one of those three fields.

GENERAL LINE and BACCALAUREATE PROGRAMS

JOHN DICK, Commander, U.S. Navy, Curricular Officer; B.S., University of Minnesota, 1940.

RAYMOND K. HOUSTON, Academic Associate; B.S., Worcester Polytechnic Institute, 1933; M.S., 1939.

DAVID L. TOBIAS, Lieutenant Commander, U.S. Navy, Assistant Curricular Officer; B.A., U.S. Naval Postgraduate School, 1965.

JAMES H. SMITH, Lieutenant Commander, U.S. Navy, Assistant Curricular Officer; B.A., University of Southern California, 1960.

JANET L. HERSLEY, Lieutenant, U.S. Navy, Administrative Officer.

OBJECTIVES:

BACCALAUREATE CURRICULA: To raise the educational level, broaden the mental outlook, and increase the professional and scientific knowledge of naval officers who do not have a baccalaureate degree.

The Baccalaureate curricula provide specialized study to meet the professional needs of the commissioned officer. The different educational backgrounds and personal needs of the students are accommodated by providing two baccalaureate curricula. The Bachelor of Science program gives emphasis to the physical environment, without neglecting the social. The Bachelor of Arts program emphasizes the social environment without neglecting the physical.

GENERAL LINE CURRICULUM: To provide instruction of about nine and one-half months duration which will prepare those foreign officers enrolled for more responsible duties in their respective operating forces, as well as with combined staffs of allied forces.

GENERAL LINE CURRICULUM (Group GL)

Required Courses

First Term

SP 001D	Basic Speech	2- 0
GV 012D	American Life and Institutions I	2- 0
Ma 010D	Basic Algebra and Trigonometry I	4- 0
NW 191D	Tactics and Combat Information Center	5- 0
NW 591D	Marine Engineering	4- 0
		17- 0

Second Term

PH 006D	Survey of Physics	5- 0
GV 013D	American Life and Institutions II	2- 0
NW 193D	Anti-Submarine Warfare	3- 0
NW 391D	Ordnance-Weapons Systems	3- 0
NW 408C	Seamanship and Marine Piloting	3- 2
		16- 2

Third Term

EE 101D	Electrical Fundamentals	3- 2
NW 502C	Damage Control and ABC Warfare Defense	4- 0
NW 395D	Mine Warfare	3- 0
NW 404C	Logistics and Naval Supply	3- 0
NW 201C	Operational Planning	2- 0
		15- 2

Fourth Term

EE 205D	Electronics Fundamentals	3- 2
PH 600D	Nucleonics Fundamentals	3- 0
NW 293D	Aviation Survey	3- 0
NW 292D	Amphibious Operations	4- 0
NW 393D	Missiles and Space Operations	3- 0
		16- 2

Elective Courses

Naval Warfare Subjects

NW 403C	Celestial Navigation	3- 0

Engineering Subjects

Mr 010D	Meteorology	3- 0

Courses in Mathematics, Physics, Chemistry and Electricity may be taken with the permission of the Curricular Officer and the Chairman of the Department involved.

Government/Humanities Subjects

GV 010D	U.S. Government	4- 0
GV 102C	International Relations	4- 0
GV 122C	International Law	4- 0
GV 142C	International Communism	4- 0
HI 101C	U.S. History I	4- 0
HI 102C	U.S. History II	4- 0
HI 103C	European History I	4- 0
HI 104C	European History II	4- 0

Courses in Literature and other Government and Humanities courses may be taken with the permission of the instructor.

BACCALAUREATE CURRICULUM

CURRICULUM NUMBER 461

The Baccalaureate Curricula include the Naval Professional courses of the General Line Curriculum and, in addition, sufficient coverage in the Humanities and Science-Engineering areas to adequately support Bachelor of Science and Bachelor of Arts degrees. From one to two calendar years are allowed for those enrolled to complete the program. Students pursuing these curricula carry a minimum load of 17 credit hours.

To be eligible for enrollment an officer must have acceptable advanced standing of 45 semester hours which can be applied toward completion of the prescribed course of study. This must include a minimum of five term hours of college-level mathematics.

The Baccalaureate Curricula meet the general degree re-

quirements of the Postgraduate School. The BS Curriculum consists of 200 term hours distributed in the following academic areas: 110 (55%) in Science-Engineering; 40 (20%) in Naval Professional; 40 (20%) in Government and Humanities; and 10 (5%) electives. The BA Curriculum consists of 200 term hours distributed as follows: 110 (55%) in Government and Humanities; 40 (20%) in Naval Professional; 40 (20%) in Science-Engineering; and 10 (5%) electives.

The Bacccalaureate Curricula schedules are shown below. Students are required to complete the courses listed there, or equivalents, either before admission to the curriculum or as part of it.

*BACHELOR OF SCIENCE
(Group BS)

First Term

CH 001D	Introductory General Chemistry I	4- 3
EN 101C	Advanced Writing for Naval Officers	3- 2
Ma 031D	College Algebra and Trigonometry	5- 0
NW 401C	Leadership and Administration	3- 0
		15- 5

Second Term

CH 002D	Introductory General Chemistry II	3- 3
HI 102C	U.S. History II	4- 0
Ma 051D	Calculus and Analytic Geometry I	5- 0
PY 010D	Introduction to Psychology	4- 0
		16- 3

Third Term

Ma 052D	Calculus and Analytic Geometry II	5- 0
PH 011D	General Physics I	4- 3
GV 010D	U.S. Government	4- 0
SP 010D	Public Speaking	3- 0
		16- 3

Fourth Term

Ma 053D	Calculus and Analytic Geometry III	5- 0
PH 012D	General Physics II	4- 3
GV 142C	International Communism	4- 0
SP 011D	Conference Procedures	3- 0
		16- 3

Fifth Term

PH 013D	General Physics III	3- 3
NW 205C	Naval Warfare Seminar	3- 0
		6- 3

Sixth Term

PH 014D	General Physics IV	4- 2
ME 561C	Mechanics I	4- 0
EE 111C	Fields and Circuits	4- 4
NW 201C	Operational Planning	2- 0
		14- 6

Seventh Term

ME 562C	Mechanics II	4- 0
EE 112C	Circuit Analysis	4- 3
GV 120C	Military Law I	3- 0
NW 404C	Logistics and Naval Supply	3- 0
NW 206C	Aero Engineering and Safety I	3- 0
		17- 3

Eighth Term

EE 221C	General Electronics I	3- 3
OC 110C	Introduction to Oceanography	3- 0
GV 121C	Military Law II	3- 0
MN 010D	Introduction to Economics	4- 0
NW 207C	Aero Engineering and Safety II	3- 0
		16- 3

Ninth Term

EE 222C	General Electronics II	3- 3
NW 208C	Aviation Accident Prevention and Crash Investigation	5- 0
NW 303C	Missiles and Space Operations	4- 0
NW 101C	Tactics and Combat Information Center	5- 0
		17- 3

Tenth Term

NW 408C	Seamanship and Marine Piloting	3- 2
NW 502C	Damage Control and ABC Warfare Defense	4- 0
NW 103C	Anti-Submarine Warfare	5- 0
NW 105C	Anti-Air Warfare	4- 0
		16- 2

*BACHELOR OF ARTS
(Group BA)

First Term

Ma 030D	Intermediate Algebra	5- 0
GV 010D	U.S. Government	4- 0
HI 101C	U.S. History I	4- 0
EN 101C	Advanced Writing for Naval Officers	3- 2
		16- 2

Second Term

SP 010D	Public Speaking	3- 0
Ma 031D	College Algebra and Trigonometry	5- 0
GV 102C	International Relations	4- 0
HI 102C	U.S. History II	4- 0
NW 201C	Operational Planning	2- 0
		18- 0

Third Term

SP 011D	Conference Procedures	3- 0
Ma 310C	Elementary Probability and Statistics	4- 0
GV 103C	Strategy for National Security	4- 0
EN 102C	Reasoning and Research Reporting	4- 0
MN 010D	Introduction to Economics	4- 0
		19- 0

Fourth Term

HI 103C	European History I	4- 0
GV 140C	Development of Western Political Thought	4- 0
LT 010D	Appreciation of Literature	3- 0
PY 010D	Introduction to Psychology	4- 0
PH 007D	General Physics I	3- 2
		18- 2

Fifth Term

PH 008D	General Physics II	3- 2
NW 205C	Naval Warfare Seminar	3- 0
		6- 2

Sixth Term

GV 120C	Military Law I	3- 0
GV 142C	International Communism	4- 0
HI 104C	European History II	4- 0
MN 114C	International Economics	4- 0
PH 009D	General Physics III	3- 2
		18- 2

Seventh Term

GV 121C	Military Law II	3- 0
GV 122C	International Law	4- 0
GV	Major Elective	4- 0
NW 206C	Aero Engineering and Safety I	3- 0
PH 010D	General Physics IV	3- 2
		17- 2

Eighth Term

GV	Major Elective	4- 0
LT	Literature Elective	3- 0
NW 207C	Aero Engineering and Safety II	3- 0
NW 101C	Tactics and Combat Information Center	5- 0
NW 303C	Missiles and Space Operations	4- 0
		19- 0

Ninth Term

GV 141C	American Traditions and Ideals	3- 0
NW 401C	Leadership and Administration	3- 0
NW 103C	Anti-Submarine Warfare	5- 0
NW 208C	Aviation Accident Prevention and Crash Investigation	5- 0
NW 404C	Logistics and Naval Supply	3- 0
		19- 0

Tenth Term

NW 105C	Anti-Air Warfare	4- 0
GV	Major Elective	4- 0
NW 408C	Seamanship and Marine Piloting	3- 2
NW 502C	Damage Control and ABC Warfare Defense	4- 0
	Elective—Government/Humanities, Science/Engineering, or Naval Professional	3- 0
		18- 2

*Electives may be substituted for courses for which exemptions are granted.

Note 1: The above are for an August input; for a January input, leave will occur during the 3rd instead of the 5th term with a slight modification in the schedule.

Note 2: 200 term hours are required for graduation. The difference between the number of hours listed above and the total required for graduation is made up by advanced credits and exemptions.

Note 3: NW 206, 207 and 208 comprise the Accident Prevention and Crash Investigation Program which was implemented in August 1964. These courses are required for aviators only.

NAVAL ENGINEERING PROGRAMS CURRICULUM NUMBER 570

Eugene Marion Henry, Commander, U.S. Navy, Curricular Officer; B.S., USNA, 1946; M.S., USNPGS, 1960.

Ernest Fischbein, Lieutenant Commander, U.S. Navy, Assistant Curricular Officer; B.S., Brooklyn College, 1949; M.A., Brooklyn College, 1953.

Objective—To provide selected officers with advanced education in ship engineering, primarily in mechanical and electrical engineering, to meet the requirements of the Navy for officers with technical and administrative competence related to shipboard engineering plants, including machinery systems, and structures. The specific areas of study are designed to include, within the various curricula, the fundamental and advanced theories of mathematics, thermodynamics, statics, dynamics, electrical power, circuits and feedback control, engineering materials, structures, atomic and nuclear physics, and nuclear power.

Description—All students initially enter a common Naval Engineering (General) Curriculum. After completion of two terms, students are selected to pursue studies in a specialty of either Mechanical or Electrical Engineering. Upon completion of the first year of study, a limited number of students in each specialty are further selected to follow an advanced three year curriculum in their specialty (Mechanical or Electrical Engineering).

The criteria for selection are academic performance, assigned quotas, tour availablility, and student preference.

The Curricula are:

Naval Engineering (Mechanical)	2 year curriculum
Naval Engineering (Electrical)	2 year curriculum
Mechanical Engineering (Advanced)	3 year curriculum
Electrical Engineering (Advanced)	3 year curriculum

For properly qualified students, the two year curricula lead to the award of a designated Bachelor of Science degree and the three year curricula lead to the award of a designated Master of Science degree.

NAVAL ENGINEERING (GENERAL) (Group NG)

OBJECTIVE—This is a two-term, common-core program followed by all officer students entering the Naval Engineering Curricula. The objective is to educate officers in the basic sciences and engineering principles as a foundation for more advanced studies in either an electrical or mechanical engineering specialty.

First Year

First Term

EE 111C	Fields and Circuits	4- 4
Ma 230D	Calculus of Several Variables	4- 0
Ma 120C	Vectors and Matrices	3- 1
ME 501C	Mechanics I	4- 0
		15- 5

Second Term

EE 112C	Circuit Analysis	4- 3
Ma 240C	Elementary Differential Equations	2- 0
Ma 251C	Elementary Infinite Series	3- 0
ME 502C	Mechanics II	4- 0
CH 103D	General Chemistry	4- 2
		17- 5

NAVAL ENGINEERING (MECHANICAL) (Group NH)

OBJECTIVE—To support the aim of the basic objective to the extent practicable within a two year period by providing officer students with a sound science-engineering basis for assuming increased technical and administrative responsibilities related to naval machinery, with primary emphasis on Mechanical Engineering aspects.

First Year

First and Second Terms

Same as Naval Engineering (General)

Third Term

Mt 201C	Engineering Materials I	3- 2
Ma 351B	Probability and Statistics	4- 2
ME 510C	Mechanics of Solids I	4- 2
ME 111C	Engineering Thermodynamics I	5- 0
LP 101E	Lecture Program I	0- 1
		16- 7

Fourth Term

EE 321C	Electromechanical Devices	3- 4
Mt 202C	Engineering Materials II	3- 2
ME 411C	Mechanics of Fluids	4- 2
ME 112C	Engineering Thermodynamics II	5- 0
LP 102E	Lecture Program II	0- 1
		15- 9

Fifth Term

Ma 416C	Numerical Methods and Fortran Programming	4- 1
MN 153C	Personnel Administration	4- 0
*SP 012D	Art of Presentation	2- 0
		10- 1

Second Year

First Term

ME 221C	Gas Dynamics and Heat Transfer	4- 2
ME 504B	Advanced Dynamics	4- 0
ME 521C	Mechanics of Solids II	4- 0
ME 711B	Mechanics of Machinery	3- 2
		15- 4

Second Term

ME 222C	Thermodynamics Laboratory	1- 4
ME 522B	Mechanics of Solids III	4- 0
ME 223B	Marine Power Plant Analysis	2- 4
PH 620B	Elementary Atomic Physics	4- 0
		11- 8

Third Term

MT 403B	Corrosion and Corrosion Protection	3- 2
ME 722B	Mechanical Vibrations	3- 2
EE 231C	Electronics I	4- 3
PH 621B	Elementary Nuclear Physics	4- 0
LP 101E	Lecture Program I	0- 1
		14- 8

Fourth Term

ME 240B	Nuclear Power Plants	4- 0
ME 622B	Experimental Mechanics	2- 2
ME 820C	Machine Design	2- 4
MN 210C	Principles of Economics	4- 0
LP 102E	Lecture Program II	0- 1
		12- 7

*For all officer students except Engineering Duty officers (1400). The latter will attend the afternoon BuShips Seminars.

MECHANICAL ENGINEERING (ADVANCED) (Group NA)

OBJECTIVE—To further the aim of the basic objective by providing officer students with a broad background of science-engineering studies in a three-year program designed to prepare them for assuming increased technical and administrative responsibilities related to naval machinery, with primary emphasis on Mechanical Engineering aspects.

First Year

Same as Naval Engineering (Mechanical)

Second Year

First Term

Ma 113B	Vector Analysis and Partial Differential Equations	4- 0
Ma 270C	Complex Variables	3- 0
ME 211B	Thermodynamics of Compressible Flow	3- 0
ME 222C	Thermodynamics Lab	1- 4
ME 511A	Mechanics of Solids II	5- 0
		16- 4

Second Term

ME 412A	Advanced Mechanics of Fluids	4- 2
ME 512A	Mechanics of Solids III	4- 0
ME 711B	Mechanics of Machinery	3- 2
EE 113B	Linear Systems Analysis	4- 3
		15- 7

Third Term

EE 411B	Feedback Control Systems I	3- 3
ME 310B	Heat Transfer	4- 2
ME 503A	Advanced Dynamics	4- 0
LP 101E	Lecture Program I	0- 1
		11- 6

Fourth Term

ME 712A	Theory of Vibrations	3- 2
ME 811B	Machine Design I	3- 2
PH 620B	Elementary Atomic Physics	4- 0
LP 102E	Lecture Program II	0- 1
		10- 5

INTERSESSIONAL PERIOD—A four to six weeks tour at selected industrial or research activities.

Third Year

First Term

EE 231C	Electronics I	4- 3
ME 612A	Experimental Mechanics	3- 2
ME 812B	Machine Design II	3- 4
PH 621B	Elementary Nuclear Physics	4- 0
		14- 9

Second Term

ME 212A	Advanced Thermodynamics	3- 0
MT 302C	Alloy Steels	3- 0
ME 241A	Nuclear Propulsion Systems I	4- 0
	Thesis	0- 8
		10- 8

Third Term

ME 242A	Nuclear Propulsion Systems II	3- 3
	Thesis	0-12
LP 101E	Lecture Program I	0- 1
		3-16

Fourth Term

MN 210C	Principles of Economics	4- 0
MT 403B	Corrosion and Corrosion Protection	3- 2
	*Elective	4- 0
	Thesis	0- 8
LP 102E	Lecture Program II	0- 1
		11-11

*Elective course must be from approved list in curricular office.

NAVAL ENGINEERING (ELECTRICAL) (Group NL)

OBJECTIVE—To support the aim of the basic objective to the extent practicable within a two year period by providing officer students with a sound science-engineering basis for assuming increased technical and administrative responsibilities related to naval machinery, with primary emphasis on Electrical Engineering aspects.

First Year

First and Second Terms

Same as Naval Engineering (General)

Third Term

EE 131C	Polyphase Circuits	3- 2
Ma 271C	Complex Variables	4- 0
ME 510C	Mechanics of Solids I	4- 2
MT 201C	Engineering Materials I	3- 2
LP 101E	Lecture Program I	0- 1
		14- 7

Fourth Term

EE 113B	Linear Systems Analysis	4- 3
EE 711C	Electrical Measurements	2- 3
Ma 351B	Probability and Statistics	4- 2
MT 202C	Engineering Materials II	3- 2
LP 102E	Lecture Program II	0- 1
		13-11

Fifth Term

Ma 416C	Numerical Methods and Fortran Programming	4- 1
MN 153C	Personnel Administration	4- 0
*SP 012D	Art of Presentation	2- 0
		10- 1

*For all officer students except Engineering Duty officers (1400). The latter will attend the afternoon BuShips Seminars.

Second Year

First Term

EE 231C	Electronics I	4- 3
EE 311C	Electric Machinery I	3- 4
ME 111C	Engineering Thermodynamics I	5- 0
PH 620B	Elementary Atomic Physics	4- 0
		16- 7

Second Term

EE 232C	Electronics II	4- 3
EE 312C	Electric Machinery II	3- 4
ME 132C	Engineering Thermodynamics II	4- 2
PH 621B	Elementary Nuclear Physics	4- 0
		15- 9

Third Term

EE 223B	Electronic Control and Measurement	3- 3
EE 411B	Feedback Control Systems I	3- 3
EE 611C	Electromagnetic Fields	4- 0
ME 210C	Applied Thermodynamics	3- 2
LP 101E	Lecture Program I	0- 1
		13- 9

Fourth Term

EE 114B	Communication Theory I	4- 0
EE 419B	Nonlinear and Sampled Systems	3- 4
EE 612C	Transmission of Electromagnetic Energy	3- 2
ME 240B	Nuclear Power Plants	4- 0
LP 102E	Lecture Program II	0- 1
		14- 7

ELECTRICAL ENGINEERING (ADVANCED) (Group NE)

Objective—To further the aim of the basic objective by providing officer students with a broad background of science-engineering studies in a three-year program designed to prepare them for assuming increased technical and administrative responsibilities related to naval machinery, with primary emphasis on Electrical Engineering aspects.

First Year

Same as Naval Engineering (Electrical).

Second Year

First Term

EE 231C	Electronics I	4- 3
EE 311C	Electric Machinery I	3- 4
ME 111C	Engineering Thermodynamics I	5- 0
PH 620B	Elementary Atomic Physics	4- 0
		16- 7

Second Term

EE 232C	Electronics II	4- 3
EE 312C	Electric Machinery II	3- 4
ME 132C	Enginering Thermodynamics II	4- 2
PH 621B	Elementary Nuclear Physics	4- 0
		15- 9

Third Term

EE 121A	Advanced Network Analysis	3- 2
EE 223B	Electronic Control and Measurement	3- 3
EE 411B	Feedback Control Systems I	3- 3
ME 210C	Applied Thermodynamics	3- 2
LP 101E	Lecture Program I	0- 1
		12-11

Fourth Term

EE 122A	Network Synthesis I	3- 2
EE 114B	Communication Theory I	4- 0
EE 412A	Feedback Control Systems II	3- 4
ME 240B	Nuclear Power Plants	4- 0
LP 102E	Lecture Program II	0- 1
		14- 7

Intersessional Period—A four to six weeks tour at selected industrial or research activities.

Third Year

First Term

EE 413A	Sampled Data Control Systems	2- 2
Ma 113B	Vector Analysis and Partial Differential Equations	4- 0
MN 210C	Principles of Economics	4- 0
	Elective	4- 0
		14- 2

Second Term

EE 621B	Electromagnetics I	3- 2
EE 951E	Seminar	0- 1
	Thesis	0-12
		3-15

Third Term

EE 315B	Marine Electrical Design I	2- 4
EE 622B	Electromagnetics II	4- 0
EE 951E	Seminar	0- 1
	Thesis	0- 8
LP 101E	Lecture Program I	0- 1
		6-14

Fourth Term

EE 261B	Nonlinear Magnetic Devices	3- 3
EE 316A	Marine Electrical Design II	2- 4
EE 491B	Nuclear Reactor Instrumentation and Control	3- 3
EE 951E	Seminar	0- 1
	Thesis	0- 8
LP 102E	Lecture Program II	0- 1
		8-20

Electives

EE 253A	Microwave Tubes	3- 2
EE 254B	Transistor Circuits	3- 3
EE 414A	Statistical Design of Control Systems	2- 2
EE 415A	Linear Control System Synthesis	3- 0
EE 416A	Nonlinear Control Systems	3- 1
EE 492A	Nuclear Reactor Power Plant Control	3- 4
EE 571A	Statistical Communication Theory	3- 2
EE 631B	Theory of Antennas	3- 3
EE 652A	Microwave Circuits and Measurements	3- 2
EE 821B	Computer Systems Technology	3- 3
OA 121A	Principles of Operations Analysis	4- 1

NAVAL MANAGEMENT AND OPERATIONS ANALYSIS PROGRAMS
CURRICULA NUMBERS 817, 367, and 360

FLETCHER H. BURNHAM, Captain, U.S. Navy; Curricular Officer; B.S., USNA, 1944; B.S. Operations Analysis, USNPGS, 1954; M.S., USNPGS, 1954.

MILES E. TWADDELL, Commander, U.S. Navy; Assistant Curricular Officer; B.S., Ohio State University, 1959; M.S. Management, USNPGS, 1962.

CLELL STEWART, Commander, U.S. Navy; Assistant Curricular Officer.

NAVAL MANAGEMENT CURRICULUM
CURRICULUM NUMBER 817
(Group MN)

OBJECTIVE—To provide officers with increased education in management which will improve their capabilities for organizing, planning, directing, coordinating and controlling activities in which the resources of men, money, and materials are combined to accomplish Navy objectives.

DESCRIPTION—The curriculum is of twelve months' duration at the graduate level commencing in August. All officers, regardless of designator, are required to participate in the "core" courses. These courses provide the foundation and tools of management and lead into the electives, which permit limited specialization in fields of interest to sponsoring bureaus and agencies.

Classroom instruction is supplemented by a guest lecturer series which affords the officer an opportunity to hear discussions of management topics by senior military officers, business executives, and prominent educators. Through the medium of a field trip to visit military installations and industrial concerns, the officer is able to discuss management philosophies and problems with leading executives in their own environment.

Successful completion of this program leads to the award of a Master of Science degree.

First Term

MN 210C	Principles of Economics	4- 0
MN 221C	Principles of Accounting	3- 0
MN 270C	Mathematics for Management	4- 0
MN 252C	Management Psychology	4- 0
EN 011D	Thesis Writing	2- 0
		17- 0

Second Term

MN 412A	Managerial Economics	4- 0
MN 422A	Managerial Accounting	3- 0
MN 471A	Probability and Statistics I	4- 2
MN 481A	Computers and Data Processing	4- 0
		15- 2

Third Term

MN 423A	Budgeting and Control	3- 0
MN 472A	Probability and Statistics II	4- 2
MN 453A	Personnel Administration and Industrial Relations	4- 0
MN 460A	Material Management	3- 0
		14- 2

Fourth Term

MN 490A	Organization Theory and Administration	5- 0
OA 471B	Operations Analysis for Navy Management	4- 0
	Electives	3- 0 to 8- 0
		12- 0 to 17- 0

Fifth Term

MN 491A	Management Policy	4- 0
	Electives	6- 0 to 12- 0
	Individual Research or Thesis	0- 8
		10- 8 to 16- 8

ELECTIVE COURSE OPTIONS

1A—Economics and Systems Analysis
Economics Sequence

Term			
IV	MN 413A	Micro-Economic Theory	4- 0
IV	MN 415A	National Income and International Trade	4- 0
V	MN 432A	Systems Analysis	4- 0
			12- 0

1B—Economics and Systems Analysis
Systems Analysis Sequence

IV	MN 413A	Micro-Economic Theory	4- 0
IV	MN 473A	Quantitative Decision Making	3- 0
V	MN 432A	Systems Analysis	4- 0
			11- 0

2—Financial Management

IV	MN 424A	Internal Control and Auditing Seminar	3- 0
IV	MN 426A	Cost Estimating and Analysis	3- 0
V	MN 425A	Comptrollership Seminar	4- 0
			10- 0

3—Personnel Management

IV	MN 495A	Organization and Management Seminar	3- 0
V	MN 455A	Personnel Administration Seminar	3- 0
V	MN 456A	Labor Relations	4- 0
			10- 0

4—Material Logistics Management

IV	MN 413A	Micro-Economic Theory	4- 0
IV	MN 461A	Procurement and Contract Administration	4- 0
V	MN 462A	Scientific Inventory Management	3- 0
			11- 0

Other available elective courses in the Management subject area are:

IV	MN 480A	Facilities Planning	3- 0
IV	MN 492A	Government and Business	4- 0

MANAGEMENT (DATA PROCESSING) CURRICULUM CURRICULUM NUMBER 367 (Group PM)

OBJECTIVE—To provide officers with a comprehensive education in computer theory and practice by which they will gain an appreciation of the capabilities and limitations of digital computers in a variety of applications, and develop their ability to analyze data processing systems and effectively manage computer-based installations.

DESCRIPTION—The curriculum is of twelve months' duration at the graduate level commencing in August. Classroom instruction is supplemented by guest lecturer and seminar series which afford the officer an opportunity to participate in discussions of management topics with senior military officers, business executives, and prominent educators. Through the medium of field trips to appropriate military installations and industrial concerns, the officer is able to analyze management and electronic data processing philosophies and problems with leading executives in their own environment.

Successful completion of this program leads to the award of a Master of Science degree.

First Term

MN 210C	Principles of Economics	4- 0
MN 490A	Organization Theory and Administration	5- 0
Ma 427C	Programming I—Introduction	3- 1
Ma 141D	Review of Analytic Geometry and Calculus	5- 0
		17- 1

Second Term

MN 422A	Managerial Accounting	3- 0
Ma 140B	Linear Algebra and Matrix Theory	4- 0
Ma 315C	Introduction to Probability and Statistics	4- 2
Ma 428B	Programming IIa	3- 1
	Elective: Sequence A or B	3- 0
		17- 3

Third Term

MN 253C	Management Psychology	3- 0
MN 381A	Data Processing Management	4- 0
OA 111B	Principles of Operations Research/ Systems Analysis	4- 2
Ma 146B	Numerical Analysis and Digital Computers	3- 0
Ma 316B	Applied Statistics I	3- 2
		17- 4

Fourth Term

MN 382A	Computer Applications	4- 0
Ma 317B	Applied Statistics II	3- 0
Ma 429A	Programming IIb	3- 0
	Elective: Sequence A or B	3- 0 to 4- 0
	Thesis	0- 4
		13- 4 to 14- 4

Fifth Term

OA 112A	Advanced Methods in Operations Analysis	4- 0
	Elective: Sequence A or B	3- 0 to 4- 0
	Elective: Sequence A or B	3- 0 to 4- 0
	Thesis	0- 4
		10- 4 to 12- 4

ELECTIVE COURSES

Sequence A (Recommended for Supply Corps Officer Students)

Term			
II	MN 460A	Material Management	3- 0
IV	MN 413A	Micro-Economic Theory	4- 0
V	MN 432A	Systems Analysis	4- 0
V	*One* course from:		
	MN 461A	Procurement and Contract Administration	4- 0
	MN 462A	Scientific Inventory Management	3- 0
			14- 0 to 15- 0

Sequence B (For Non-Supply Corps Officer Students)

II	Ma 241C	Elementary Differential Equations	3- 0
IV	*One* course from:		
	OA 293B	Search Theory	4- 0
	OA 391B	Games of Strategy	3- 2
	Ma 355A	System Reliability and Life Testing	3- 0
V	*Two* courses from:		
	MN 462A	Scientific Inventory Management	3- 0
	OA 393B	Introduction to War Gaming	2- 2
	Ma 306A	Selected Topics in Advanced Statistics I	3- 1
	Ma 705B	Set Theory	3- 0
			12- 0 to 13- 1

ELEMENTS OF MANAGEMENT CURRICULUM

OBJECTIVE—To acquaint officers with the principles of management and administration, examine current management problems within the Naval Establishment and general approaches to their solution, and provide familiarity with modern practices and methods of management in civilian activities by emphasizing ways in which such techniques may be effectively applied to Navy situations.

DESCRIPTION—The curriculum, which is four weeks in length, is presented once a year during the summer to selected officers sponsored by Bureaus, Offices, and activities of the Department of the Navy who attend on a temporary additional duty basis.

The schedule of instruction is as follows:

a. Morning sessions—special short courses in management subjects:

MN 020D	Financial Management	1- 0
MN 040D	Production Management	1- 0
MN 053D	Personnel Management	1- 0
MN 090D	Principles of Organization and Management	1- 0

b. Afternoon seminars—sponsored by Bureaus and Offices of the Naval Establishment, and the Naval Postgraduate School.

DEFENSE MANAGEMENT PROGRAM

OBJECTIVE—To present a course of study which analyzes the basic concepts and practices of general management, problem solving, and decision making in the context of the Defense Management Systems (program planning, programming, budgeting and related activities within the Department of Defense) and provides a cross-fertilization of ideas on Defense Management as a basis for understanding and improvement; this program to include instruction in the principles and procedures of such systems as related to the management of financial, logistic and manpower resources.

DESCRIPTION—The course, which is four weeks in length, will be presented seven times a year, commencing in September 1965.

Classes will be composed of approximately fifty to sixty senior military and civilian personnel representing various DOD components including OSD, the Defense Agencies, and the military departments, who will attend on a temporary additional duty basis. Classes will be organized into seminars of 10-15 students, each containing a balanced number of personnel from DOD components represented at the particular session, and varying degrees of experience in the Defense Management System, plus assigned foreign nationals as appropriate.

The curriculum is currently being prepared. It will include study in the following major areas:

a. General management to include accepted concepts and principles, organization for management, and economies of resource management as they relate to defense management.

b. Management theories and techniques including systems analysis/cost effectiveness, cost models, cost analysis and validation, and information systems.

c. Defense management methodology and the interrelationship of program planning, programming and budgeting.

Technical supervision of the curriculum is exercised by the Assistant Secretary of Defense (Comptroller) in coordination with the Assistant Secretary of Defense (Installations and Logistics)—(Defense Logistics Management Training Board). Overall coordination of the course will be exercised by the Assistant Secretary of Defense (Manpower).

OPERATIONS RESEARCH/SYSTEMS ANALYSIS CURRICULUM
CURRICULUM NUMBER 360
(Group RO)

OBJECTIVE—To develop the analytical ability of officers by providing a sound background and education in scientific and analytical methods so that they may formulate new concepts and programs in operations research/systems analysis, apply the result of operations research/systems analysis with greater effectiveness, and solve operations analysis problems which arise both in the fleet and ashore.

DESCRIPTION—The curriculum is normally of two years' duration at the graduate level, with new students enrolled in January and August of each year. Classroom work is augmented by guest lecturer-seminar series which permit officers to gain first-hand information as to practical applications of operations research/systems analysis principles and techniques. Between the first and second year of the program students are assigned individually as working members of various industrial or military organizations which are engaged in operations analysis of military problems. Successful completion of the two year curriculum leads to the award of a Master of Science degree.

A third year of study may be offered to particularly well qualified officers. Selection is based upon the expressed desires of the individual, the Superintendent's appraisal of his academic ability and prospects, and his availability for the additional year of duty ashore.

First Year

First Term

Ma 180C	Vector, Matrices, and Vector Spaces	3- 1
Ma 181D	Partial Derivatives and Multiple Integrals	4- 1
Ma 301C	Basic Probability and Set Theory	4- 0
OA 421C	Introduction to Digital Computers	5- 0
OA 891E	Seminar I	0- 2
		16- 4

Second Term

Ma 182C	Differential Equations and Vector Analysis	5- 0
Ma 302B	Second Course in Probability	3- 2
OA 291C	Introduction to Operations Analysis	4- 0
OA 892E	Seminar II	0- 2
Ph 242C	Radiation	3- 0
MN 211C	Principles of Economics	3- 0
		18- 4

Third Term

Ma 196B	Matrix Theory	3- 0
Ma 303B	Theory and Techniques in Statistics I	3- 2
OA 292B	Methods of Operations Research/ Systems Analysis	4- 0
OA 393B	Introduction to War Gaming	2- 2
OA 893E	Seminar III	0- 2
	Core Sequence I-3	4- 0
		16- 6

Fourth Term

Ma 193C	Set Theory and Integration	2- 0
Ma 304B	Theory and Techniques in Statistics II	3- 0
OA 293B	Search Theory	4- 0
OA 391B	Games of Strategy	3- 2
OA 894E	Seminar IV	0- 2
	Core Sequence I-4	4- 0
		16- 4

Second Year

First Term

Ma 183B	Fourier Series and Complex Variables	4- 0
OA 211A	Linear Programming	4- 1
OA 236A	Utility Theory	3- 0
OA 891E	Seminar I	0- 2
	Core Sequence II-1	3- 0 to 4- 0
	Elective Sequence (Required) (1)	3- 0 to 5- 0
	Elective Sequence (Optional)	3- 0 to 5- 0
		20- 3 to 25- 3

Second Term

OA 234A	Queueing Theory	3- 0
OA 501A	Introduction to Systems Analysis	4- 0
OA 892E	Seminar II	0- 2
	Core Sequence II-2	3- 1 to 4- 0
	Elective Sequence (Required) (1)	3- 0 to 5- 0
	Elective Sequence (Optional)	3- 0 to 5- 0
		16- 3 to 21- 2

Third Term

MN 426A	Cost Estimating and Analysis	3- 0
OA 893E	Seminar III	0- 2
	Core Sequence II-3	3- 1 to 4- 0
	Elective Sequence (Required) (1)	3- 0 to 5- 0
	Elective Sequence (Optional)	3- 0 to 5- 0
	Thesis	0- 8
		12-11 to 17-10

Fourth Term

OA 502A	Systems Analysis	4- 0
OA 894E	Seminar IV	0- 2
	Core Sequence II-4	3- 0 to 4- 0
	Elective Sequence (Required) (1)	3- 0 to 5- 0
	Elective Sequence (Optional)	3- 0 to 5- 0
	Thesis	0- 4
		13- 6 to 18- 6

Core Course Sequences A and B

Core Sequence A is designed to meet the general "Navy need" and is required of all students except Supply Corps officers.

Core Sequence B is designed to meet the needs of the Supply Corps, and may be elected by Supply Corps officers in place of Core Sequence A.

CORE SEQUENCE A
(General)

I-3	Ph 141B	Analytical Mechanics	4- 0
I-4	MN 413A	Micro-Economic Theory	4- 0
II-1	Ph 424B	Fundamental Acoustics	4- 0
II-2	Ph 360B	Electricity and Magnetism	4- 0
II-3	Ph 630B	Elementary Atomic Physics	4- 0
II-4	Ph 621B	Elementary Nuclear Physics	4- 0

CORE SEQUENCE B
(Supply Corps Officers)

I-3	MN 381A	Data Processing Management	4- 0
I-4	MN 382A	Computer Applications	4- 0
II-1	Ma 307A	Stochastic Process I	3- 0
II-2	Ma 305A	Design of Experiments	3- 1
II-3	OA 213A	Inventory Control	3- 0
II-4	Ma 398B	Sampling Inspection and Quality Control	3- 1

Required Elective Sequences

Each student must select one of the following Sequences.

In addition, optional electives may be selected from this list. All optional electives selected must, however, be approved by the Chairman, Department of Operations Analysis.

Term Offered	*Course Number*	*Course Title*	*Term Hours*
		SEQUENCE I	
I	Ma 307A	Stochastic Process I	3- 0
II	Ma 305A	Design of Experiments	3- 1
III	Ma 306A	Selected Topics in Advanced Statistics I	3- 1
IV	Ma 308A	Stochastic Process II	3- 0
		SEQUENCE II	
I	OA 396A	Advanced Projects in Operations Research/Systems Analysis I	2- 0 to 5- 0
II	Ma 305A	Design of Experiments	3- 1
III	OA 225A	Air Warfare	3- 0
IV	OA 394A	War Gaming	2- 2
		SEQUENCE III	
I	Ma 307A	Stochastic Process I	3- 0
II	OA 217A	Theory of Pattern Recognition	3- 0
III	OA 213A	Inventory Control	3- 0
IV	Ma 355A	System Reliability and Life Testing	3- 0
		SEQUENCE IV	
I	Ma 524A	Boolean Algebra	3- 0
II	Ma 428B	Programming IIa	3- 1
III	Ma 146B	Numerical Analysis and Digital Computers	3- 0
IV	Ma 429A	Programming IIb	3- 0
		SEQUENCE V	
I	MN 436A	Economic Analysis	4- 0
II	OA 202A	Econometrics	3- 0
III	OA 214A	Graph Theory	3- 0
IV	OA 235A	Decision Criteria	3- 0
		SEQUENCE VI	
I	OA 216A	Cybernetics	3- 0
II	OA 392A	Decision Theory	3- 0
III	OA 214A	Graph Theory	3- 0
IV	OA 297A	Selected Topics in Operations Research/Systems Analysis I	2- 0 to 5- 0
		SEQUENCE VII	
I	OA 396A	Advanced Projects in Operations Research/Systems Analysis I	2- 0 to 5- 0
II	OA 212A	Nonlinear and Dynamic Programming	3- 1
III	Ma 248B	Differential Equations for Optimum Control	3- 0
IV	OA 297A	Selected Topics in Operations Research/Systems Analysis I	2- 0 to 5- 0

ORDNANCE ENGINEERING PROGRAMS
CURRICULA NUMBERS 521 and 530

BRUNO MUSSETTO, Commander, U.S. Navy, Curricular Officer; B.S., Mechanical Engineering, Swarthmore College, 1946; B.S., Electrical Engineering, USNPGS, 1961.

RICHARD L. KEENAN, Lieutenant Commander, U.S. Navy, Assistant Curricular Officer; B.S.Ed., Lock Haven State Teachers College, 1953; B.S., Electrical Engineering, USNPGS, 1962.

NUCLEAR ENGINEERING (EFFECTS)

CURRICULUM NUMBER 521
(Group RZ)

OBJECTIVE—To educate selected officers in such portions of the fundamental sciences as will furnish an advanced technical understanding of the phenomenology of the blast and of the thermal, nuclear, and biological aspects of nuclear weapons effects, including their employment and defensive situations.

DESCRIPTION—This curriculum is sponsored by the Defense Atomic Support Agency as a joint-service course for selected officers of the Army, Navy, Air Force, Marine Corps, and Coast Guard, and affords the opportunity to qualify for the degree Master of Science in Physics. For those not academically qualified for the Master of Science degree a thesis is not required and certain elective sequences appropriate to the curriculum objectives may be chosen in lieu of the thesis during the second year.

For a limited number of exceptionally well-qualified students a third year of instruction may be granted. These students are selected at the end of the first year. The second- and third-year curricula are then tailored to individual needs, consistent with the requirements of DASA and the parent service.

First Year

First Term

CH 106D	Principles of Chemistry I	3- 2
Ma 120C	Vectors and Matrices	3- 1
Ma 230D	Calculus of Several Variables	4- 0
Ma 252C	Series and Differential Equations	4- 0
		14- 3

Second Term

CH 109D	General and Organic Chemistry	3- 2
Ma 253C	Differential Equations and Series	3- 0
PH 151C	Mechanics I	4- 1
PH 240C	Optics and Spectra	3- 3
PH 701C	Introduction to the Methods of Theoretical Physics	4- 0
		17- 6

Third Term

Ma 351B	Probability and Statistics	4- 2
PH 152B	Mechanics II	4- 0
PH 365C	Electricity and Magnetism	4- 1
PH 530C	Thermodynamics	3- 0
PH 635B	Atomic Physics I	5- 0
LP 101E	Lecture Program I	0- 1
		20- 4

Fourth Term

PH 153A	Mechanics III	4- 0
PH 366B	Electromagnetism	4- 0
PH 541B	Introductory Statistical Physics	4- 0
PH 636B	Atomic Physics II	4- 3
PH 750E	Physics Colloquium	0- 1
LP 102E	Lecture Program II	0- 1
	Thesis	0- 1
		16- 6

INTERSESSIONAL PERIOD—Field trip to Sandia Base for specially tailored Weapons Employment Course given by the Special Weapons Training Group of the Field Command, DASA.

Second Year

First Term

EC 591B	Blast and Shock Effects	3- 0
EE 291C	Electronics I (Nuclear)	3- 3
PH 350B	Special Topics in Electromagnetism (Non-MS students)	4- 0
PH 367A	Advanced Electromagnetism I (MS students)	4- 0
PH 637B	Nuclear Physics I	3- 0
PH 750E	Physics Colloquium	0- 1
	Thesis (MS students)	0- 6
	MS students	13-10
	Non-MS students	13- 4

Second Term

BI 800C	Fundamentals of Biology	6- 0
EE 292C	Electronics II (Nuclear)	3- 3
PH 638B	Nuclear Physics II (Non-MS students)	3- 3
PH 639A	Nuclear Physics II (MS students)	4- 3
PH 750E	Physics Colloquium	0- 1
	Thesis (MS students	0- 6
	Elective (Non-MS students)	4- 0
	MS students	13-13
	Non-MS students	16- 7

Third Term

BI 801B	Animal Physiology	6- 0
ME 547C	Statics and Strength of Materials	5- 0
PH 441B	Shock Waves in Fluids	4- 0
PH 750E	Physics Colloquium	0- 1
LP 101E	Lecture Program I	0- 1
	Thesis (MS students)	0- 6
	Elective (Non-MS students)	3- 0
	MS students	15- 8
	Non-MS students	18- 2

Fourth Term

BI 802A	Radiation Biology	6- 0
CH 551A	Radiochemistry I	2- 4
ME 548B	Structural Theory	5- 0
PH 750E	Physics Colloquium	0- 1
LP 102E	Lecture Program II	0- 1
	Thesis (MS students)	0- 6
	Elective (Non-MS students)	3- 0
	MS students	13-12
	Non-MS students	16- 6

WEAPONS SYSTEMS ENGINEERING CURRICULA

CURRICULUM NUMBER 530

Basic Objective—To provide selected officers with an advanced technical education on a broad foundation encompassing the basic scientific and engineering principles underlying the field of weapons. The specific areas of study and the level to be attained are formulated for each curriculum to insure a sound basis for technical competence and for such subsequent growth as may be required for the operation, maintenance, design, development, or production of advanced weapons systems.

Description—All officers ordered for instruction in Weapons Systems Engineering initially matriculate in the 2-year General Curriculum. At the end of the first year, officer students will be selected for the 3-year Advanced Weapons Systems Engineering Curricula within the quotas assigned by the Chief of Naval Personnel. This selection is based on the expressed choice of the individual and the Superintendent's appraisal of his academic ability. For properly qualified entering students, the 2-year General Curriculum leads to the award of a bachelor's degree and the 3-year curricula lead to the award of a master's degree in a scientific or engineering field. A 2-year Weapons Systems (Special) Curriculum is offered to selected officer students of allied countries.

WEAPONS SYSTEMS ENGINEERING (GENERAL)

(Group WG)

Objective—To support the aims of the basic objective to the maximum extent practicable within the 2-year period with emphasis on the fundamentals of Weapons Systems Engineering.

First Year (Common to All)

First Term

CH 106D	Principles of Chemistry I	3- 2
EE 111C	Fields and Circuits	4- 4
Ma 120C	Vectors and Matrices	3- 1
Ma 230D	Calculus of Several Variables	4- 0
		14- 7

Second Term

CH 107D	Principles of Chemistry II	3- 2
EE 112C	Circuit Analysis	4- 3
Ma 254C	Taylor and Fourier Series	3- 0
Ma 255C	Differential Equations and Series Solutions	3- 0
Ma 260C	Vector Analysis	3- 0
		16- 5

Third Term

EC 611C	General Thermodynamics	3- 2
EE 231C	Electronics I	4- 3
Ma 271C	Complex Variables	4- 0
PH 151C	Mechanics I	4- 1
LP 101E	Lecture Program I	0- 1
		15- 7

Fourth Term

EE 232C	Electronics II	4- 3
EE 321C	Electromechanical Devices	3- 4
PH 152B	Mechanics II	4- 0
PH 265C	Physical Optics	4- 2
LP 102E	Lecture Program II	0- 1
		15-10

Intersessional Period—Enrollment in MN 191C, MN 210C, and SP 012D at the U.S. Naval Postgraduate School.

Second Year

First Term

CH 407B	Physical Chemistry	3- 2
EE 113B	Linear Systems Analysis	4- 3
EE 234C	Pulse Techniques and High Frequency Tubes	3- 3
EE 611C	Electromagnetic Fields	4- 0
		14- 8

Second Term

EE 411B	Feedback Control Systems I	3- 3
EE 612C	Transmission of Electromagnetic Energy	3- 2
Ma 351B	Probability and Statistics	4- 2
PH 450C	Underwater Acoustics	3- 2
		13- 9

Third Term

EE 419B	Non-Linear and Sampled Systems	3- 4
EE 431C	Introduction to Radar	3- 3
Ma 352B	Applied Engineering Statistics	2- 2
PH 630B	Elementary Atomic Physics	4- 0
LP 101E	Lecture Program I	0- 1
		12-10

Fourth Term

EC 542B	Reaction Motors	3- 2
EC 571B	Explosives Chemistry	3- 2
Ma 416C	Numerical Methods and Fortran Programming	4- 1
PH 621B	Elementary Nuclear Physics	4- 0
PH 622B	Nuclear Physics Laboratory	0- 3
LP 102E	Lecture Program II	0- 1
		14- 9

This curriculum affords the opportunity to qualify for the degree Bachelor of Science in Electrical Engineering.

ADVANCED WEAPONS SYSTEMS ENGINEERING (CHEMISTRY)
(Group WC)

OBJECTIVE—To further the aims of the basic objective by providing officer students with a broad background of selected science-engineering studies oriented toward those weapons systems dependent upon chemical energy for propulsion or explosive applications, with Chemistry as the major field of study and Electrical Engineering as the principal minor field.

First Year (Common to All)

Same as WEAPONS SYSTEMS ENGINEERING (GENERAL)

Second Year

First Term

CH 108C	Inorganic Chemistry	3- 4
CH 231C	Quantitative Analysis	2- 4
EE 234C	Pulse Techniques and High Frequency Tubes	3- 3
PH 365C	Electricity and Magnetism	4- 1
		12-12

Second Term

CH 311C	Organic Chemistry I	3- 2
CH 443B	Physical Chemistry I	4- 3
Ma 416C	Numerical Methods and Fortran Programming	4- 1
PH 670B	Atomic Physics I	3- 0
		14- 6

Third Term

CH 312C	Organic Chemistry II	3- 2
CH 444B	Physical Chemistry II	3- 3
Ma 351B	Probability and Statistics	4- 2
PH 671B	Atomic Physics II	3- 3
LP 101E	Lecture Program I	0- 1
		13-11

Fourth Term

CH 150A	Inorganic Chemistry, Advanced	4- 3
CH 313B	Organic Chemistry III	3- 2
CH 454B	Instrumental Methods of Analysis	3- 3
CH 800E	Chemistry Seminar	0- 1
Ma 352B	Applied Engineering Statistics	2- 2
LP 102E	Lecture Program II	0- 1
	Thesis	0- 1
		12-13

INTERSESSIONAL PERIOD—Field assignment at a representative ordnance or industrial installation.

Third Year

First Term

CH 328A	Physical Organic Chemistry I	4- 0
CH 467A	Quantum Chemistry I	3- 0
CH 470A	Chemical Thermodynamics	3- 0
CH 800E	Chemistry Seminar	0- 1
	Thesis	0- 6
		10- 7

Second Term

CH 329A	Physical Organic Chemistry II	3- 0
CH 800E	Chemistry Seminar	0- 1
EE 113B	Linear Systems Analysis	4- 3
CH/EC	Elective	3- 2
	Thesis	0- 6
		10-12

Third Term

CH 800E	Chemistry Seminar	0- 1
EC 542B	Reaction Motors	3- 2
EE 411B	Feedback Control Systems I	3- 3
CH/EC	Elective	3- 2
LP 101E	Lecture Program I	0- 1
	Thesis	0- 6
		9-15

Fourth Term

CH 800E	Chemistry Seminar	0- 1
EE 419B	Non-Linear and Sampled Systems	3- 4
PH 621B	Elementary Nuclear Physics	4- 0
LP 102E	Lecture Program II	0- 1
	Elective	3- 2
	Thesis	0- 6
		10-14

Successful completion of this curriculum leads to the degree Master of Science in Chemistry.

ADVANCED WEAPONS SYSTEMS ENGINEERING (MATERIALS)
(Group WM)

OBJECTIVE—To further the aims of the basic objective by providing officer students with a broad background of selected science-engineering studies oriented toward those aspects of Weapons Systems having to do with the nature, characteristics, and behavior of component materials, with Materials Science as the major field of study.

First Year (Common to All)

Same as WEAPONS SYSTEMS ENGINEERING (GENERAL)

Second Year

First Term

EE 234C	Pulse Techniques and High Frequency Tubes	3- 3
ME 540C	Mechanics of Solids	3- 2
Mt 201C	Engineering Materials I	3- 2
PH 365C	Electricity and Magnetism	4- 1
		13- 8

Second Term

CH 443B	Physical Chemistry I	4- 3
Cr 271A	Crystallography and X-ray Techniques	3- 2
Mt 202C	Engineering Materials II	3- 2
PH 670B	Atomic Physics I	3- 0
		13- 7

Third Term

CH 444B	Physical Chemistry II	3- 3
Ma 351B	Probability and Statistics	4- 2
Mt 205A	Advanced Physical Metallurgy	3- 4
PH 671B	Atomic Physics II	3- 3
LP 101E	Lecture Program I	0- 1
		13-13

Fourth Term

CH 800E	Chemistry Seminar	0- 1
Ma 352B	Applied Engineering Statistics	2- 2
Mt 206A	Advanced Physical Metallurgy	3- 4
Mt 221B	Phase Transformations	3- 0
PH 730A	Physics of the Solid State	4- 2
LP 102E	Lecture Program II	0- 1
	Thesis	0- 1
		12-11

INTERSESSIONAL PERIOD—Field assignment at a representative ordnance or industrial installation.

Third Year

First Term

CH 581A	Properties of Ceramic Materials	4- 0
CH 800E	Chemistry Seminar	0- 1
Ma 416C	Numerical Methods and Fortran Programming	4- 1
Mt 222A	Mechanical Properties of Solids	3- 0
	Thesis	0- 6
		11- 8

Second Term

CH 800E	Chemistry Seminar	0- 1
EC 521A	Plastics and High Polymers	3- 2
EE 113B	Linear Systems Analysis	4- 3
Mt 312A	Materials Systems for Adverse Environments	4- 0
	Thesis	0- 6
		11-12

Third Term

CH 800E	Chemistry Seminar	0- 1
EC 542B	Reaction Motors	3- 2
EE 411B	Feedback Control Systems I	3- 3
LP 101E	Lecture Program I	0- 1
	Elective	3- 2
	Thesis	0- 6
		9-15

Fourth Term

CH 800E	Chemistry Seminar	0- 1
EE 419B	Non-Linear and Sampled Systems	3- 4
Mt 304A	Special Topics in Materials Science	4- 0
PH 621B	Elementary Nuclear Physics	4- 0
LP 102E	Lecture Program II	0- 1
	Thesis	0- 6
		11-12

Successful completion of this curriculum leads to the degree Master of Science in Materials Science.

ADVANCED WEAPONS SYSTEMS ENGINEERING (AIR/SPACE PHYSICS)

(Group WP)

OBJECTIVE—To further the aims of the basic objective by providing officer students with a broad background of selected science-engineering studies underlying air and space weapons systems, with Physics as the major field of study and Electrical Engineering as the principal minor field.

First Year (Common to All)

Same as WEAPONS SYSTEMS ENGINEERING (GENERAL)

Second Year

First Term

CH 407B	Physical Chemistry	3- 2
EE 234C	Pulse Techniques and High Frequency Tubes	3- 3
PH 153A	Mechanics III	4- 0
PH 365C	Electricity and Magnetism	4- 1
		14-6

Second Term

Ma 351B	Probability and Statistics	4- 2
Mc 406A	Introductory Control and Guidance	4- 0
PH 366B	Electromagnetism	4- 0
PH 670B	Atomic Physics I	3- 0
		15- 2

Third Term

Ma 352B	Applied Engineering Statistics	2- 2
PH 367A	Advanced Electromagnetism I	4- 0
PH 541B	Introductory Statistical Physics	4- 0
PH 671B	Atomic Physics II	3- 3
LP 101E	Lecture Program I	0- 1
		13- 6

Fourth Term

Ma 416C	Numerical Methods and Fortran Programming	4- 1
PH 637B	Nuclear Physics I	3- 0
PH 654A	Plasma Physics I	4- 0
PH 730A	Physics of the Solid State	4- 2
PH 750E	Physics Colloquium	0- 1
LP 102E	Lecture Program II	0- 1
	Thesis	0- 1
		15- 6

INTERSESSIONAL PERIOD—Field assignment at a representative ordnance or industrial installation.

Third Year

First Term

Ae 171A	Vector Mechanics of Fluid Flow	3- 2
PH 639A	Nuclear Physics II	4- 3
PH 655A	Plasma Physics II	4- 0
PH 750E	Physics Colloquium	0- 1
	Thesis	0- 6
		11-12

Second Term

Ae 172A	Laminar and Turbulent Flow	3- 2
EE 113B	Linear Systems Analysis	4- 3
PH 750E	Physics Colloquium	0- 1
	Elective	3- 0
	Thesis	0- 6
		10-12

Third Term

Ae 173A	Compressible Fluids I	4- 0
EE 411B	Feedback Control Systems I	3- 3
EC 542B	Reaction Motors	3- 2
PH 750E	Physics Colloquium	0- 1
LP 101E	Lecture Program I	0- 1
	Thesis	0- 6
		10-13

Fourth Term

Ae 174A	Compressible Fluids II	3- 2
EE 419B	Non-Linear and Sampled Systems	3- 4
PH 750E	Physics Colloquium	0- 1
LP 102E	Lecture Program II	0- 1
	Elective	3- 0
	Thesis	0- 6
		9-14

This curriculum affords the opportunity to qualify for the degree Master of Science in Physics.

ADVANCED WEAPONS SYSTEMS ENGINEERING (UNDERWATER PHYSICS) (Group WU)

OBJECTIVE—To provide students with a broad background of science-engineering studies underlying Underwater Weapons Systems with Physics as the major field of study and Electrical Engineering as the principal minor field.

First Year (Common to All)

Same as WEAPONS SYSTEMS ENGINEERING (GENERAL)

Second Year

First Term

CH 407B	Physical Chemistry	3- 2
EE 234C	Pulse Techniques and High Frequency Tubes	3- 3
PH 365C	Electricity and Magnetism	4- 1
PH 431B	Fundamental Acoustics	4- 0
		14- 6

Second Term

Ma 351B	Probability and Statistics	4- 2
PH 366B	Electromagnetism	4- 0
PH 432B	Underwater Acoustics	4- 3
PH 670B	Atomic Physics I	3- 0
		15- 5

Third Term

Ma 352B	Applied Engineering Statistics	2- 2
PH 367A	Advanced Electromagnetism I	4- 0
PH 471A	Acoustics Research	0- 3
PH 541B	Introductory Statistical Physics	4- 0
PH 671B	Atomic Physics II	3- 3
LP 101E	Lecture Program I	0- 1
		13- 9

Fourth Term

Ma 416C	Numerical Methods and Fortran Programming	4- 1
Oc 110C	Introduction to Oceanography	3- 0
PH 480E	Acoustics Colloquium	0- 1
PH 621B	Elementary Nuclear Physics	4- 0
PH 622B	Nuclear Physics Laboratory	0- 3
LP 102E	Lecture Program II	0- 1
	Thesis	0- 1
		11- 7

INTERSESSIONAL PERIOD—Field assignment at a representative ordnance or industrial installation.

Third Year

First Term

OA 121A	Survey of Operations Analysis	4- 1
PH 161A	Fluid Mechanics	3- 0
PH 461A	Transducer Theory and Design	3- 3
PH 750E	Physics Colloquium	0- 1
	Thesis	0- 6
		10-11

Second Term

EE 113B	Linear Systems Analysis	4- 3
PH 162A	Advanced Hydrodynamics	3- 0
PH 433A	Propagation of Waves in Fluids	3- 0
PH 750E	Physics Colloquium	0- 1
	Thesis	0- 6
		10-10

Third Term

EC 542B	Reaction Motors	3- 2
EE 411B	Feedback Control Systems	3- 3
PH 750E	Physics Colloquium	0- 1
LP 101E	Lecture Program I	0- 1
	Thesis	0- 6
	Elective	3- 0
		9-13

Fourth Term

EE 419B	Non-Linear and Sampled Systems	3- 4
PH 442A	Finite Amplitude Waves in Fluids	3- 0
PH 480E	Acoustics Colloquium	0- 1
LP 102E	Lecture Program II	0- 1
	Thesis	0- 6
	Elective	3- 0
		9-12

Successful completion of this curriculum leads to the degree Master of Science in Physics.

ADVANCED WEAPONS SYSTEMS ENGINEERING (ELECTRONICS)
(Group WX)

Objective—To provide students with a broad background of science-engineering studies underlying modern weapons control systems with primary emphasis on electronics control systems and methods of digital computation.

First Year (Common to All)

Same as WEAPONS SYSTEMS ENGINEERING (GENERAL)

Second Year

First Term

EE 113B	Linear Systems Analysis	4- 3
EE 233B	Communication Circuits and Systems	4- 3
EE 621B	Electromagnetics I	3- 2
PH 630B	Elementary Atomic Physics	4- 0
		15- 8

Second Term

EE 114B	Communication Theory I	4- 0
EE 213C	Pulse and Waveforming Circuits	4- 3
EE 622B	Electromagnetics II	4- 0
PH 723B	Theory of Solid State and Quantum Devices	4- 0
		16- 3

Third Term

EE 411B	Feedback Control Systems I	3- 3
EE 253A	Microwave Tuhes	3- 2
EE 811C	Electronic Computers	3- 3
Ma 351B	Probability and Statistics	4- 2
LP 101E	Lecture Program I	0- 1
		13-11

Fourth Term

EE 412A	Feedback Control Systems II	3- 4
EE 433A	Radar Systems	4- 0
EE 812B	Logical Design and Circuitry	4- 0
Ma 352B	Applied Engineering Statistics	2- 2
LP 102E	Lecture Program II	0- 1
	Thesis	0- 1
		13- 8

Intersessional Period—Field assignment at a representative ordnance or industrial installation.

Third Year

First Term

EE 413A	Sampled Data Control Systems	2- 2
EE 551A	Information Networks	3- 2
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 6
	Elective	3- 2
		8-13

Second Term

EE 414A	Statistical Design of Control Systems	2- 2
EE 462A	Automation and System Control	3- 3
EE 951E	Thesis Seminar	0- 1
	Thesis	0- 6
	Elective	3- 2
		8-14

Third Term

EC 542B	Reaction Motors	3- 2
EE 121A	Advanced Network Analysis	3- 2
EE 473A	Missile Guidance Systems	3- 0
EE 951E	Thesis Seminar	0- 1
	Lecture Program I	0- 1
	Thesis	0- 6
		9-12

Fourth Term

EE 122A	Network Synthesis I	3- 2
EE 461A	Systems Engineering	3- 2
EE 821B	Computer Systems Technology	3- 3
EE 951E	Thesis Seminar	0- 1
LP 102E	Lecture Program II	0- 1
	Thesis	0- 6
		9-15

Successful completion of this curriculum leads to the degree Master of Science in Engineering Electronics.

WEAPONS SYSTEMS (SPECIAL)
(Group WS)

Objective—To provide selected foreign officers with a technical education in the principal science-engineering fields of Electrical Engineering, Physics, and Chemistry underlying weapons systems.

Both the first and second year of this 2-year program are the same as the Weapons Systems Engineering (General) Curriculum except for minor modifications to fit the needs of individual students.

This curriculum affords the opportunity to qualify for the degree Bachelor of Science in Electrical Engineering.

CURRICULA CONDUCTED AT CIVILIAN UNIVERSITIES

Curriculum	*Number*	*Length*	*Institution*	*Liaison Official*	*Curricular Supervisory Control Authority*
Business Administration	810	2 yrs.	Harvard	CO, NROTC	BUWEPS
			Stanford	CO, NROTC	BUWEPS
Civil Engineering (Advanced)	470	1-2 yrs.	Georgia Tech.	CO, NROTC	BUDOCKS
			M.I.T.	CO, NROTC	BUDOCKS
Typical Options:			Princeton	CO, NROTC	BUDOCKS
Structures			Purdue	CO, NROTC	BUDOCKS
Soil Mechanics			R.P.I.	CO, NROTC	BUDOCKS
Sanitary Engineering			Stanford	CO, NROTC	BUDOCKS
Waterfront Facilities			Texas A.&M.	Senior Officer Student	BUDOCKS
Facilities Planning			Tulane	CO, NROTC	BUDOCKS
Construction Engineering			Cal. (Berkeley)	CO, NROTC	BUDOCKS
Civil Engineering Administration			U. of Colo.	CO, NROTC	BUDOCKS
Deep Ocean Construction Engineering			U. of Ill.	CO, NROTC	BUDOCKS
			U. of Mich.	CO, NROTC	BUDOCKS
			U. of Minn.	CO, NROTC	BUDOCKS
			U. of Wash.	CO. NROTC	BUDOCKS
Electrical Engineering (CEC)	471	15-24 mos.	U. of Mich.	CO, NROTC	BUDOCKS
Engineering Electronics (CEC)	472	12-18 mos.	U. of Mich.	CO, NROTC	BUDOCKS
Financial Management	812	1 yr.	Geo. Wash. U.	Senior Officer Student	USNPGS
Geodesy	475	2 yrs.	Ohio St. U.	CO, NROTC	USNPGS
International Relations	671	1 yr.	American U.	Senior Officer Student	USNPGS
			Cal. (Berkeley)	CO, NROTC	USNPGS
			Harvard	CO, NROTC	USNPGS
Law (Army Judge Advocate Officers Advanced Course)	881	9 mos.	U. of Virginia	CO, NROTC	JAG
Management and Industrial Engineering	540	1 yr.	R.P.I.	CO, NROTC	USNPGS
Mechanical Engineering (CEC)	473	1 yr.	R.P.I.	CO, NROTC	BUDOCKS
Metallurgical Engineering	640	9 mos.	Carnegie Tech.	Senior Officer Student	USNPGS
Naval Construction and Engineering	510	3 yrs.	M.I.T.	CO. NROTC	BUSHIPS
			Webb Inst.	Senior Officer Student	BUSHIPS
Nuclear Engineering (Advanced)	520	14 mos.	M.I.T.	CO, NROTC	BUSHIPS
Nuclear Power Engineering (CEC)	572	15-20 mos.	Cal. (Berkeley)	CO, NROTC	BUDOCKS
			U. of Mich.	CO, NROTC	BUDOCKS
Oceanography	440	2 yrs.	U. of Miami (Florida)	Senior Officer Student	USNPGS
			U. of Washington	CO, NROTC	USNPGS
			Texas A.&M.	Senior Officer Student	USNPGS
			U. of Cal. (San Diego)	Senior Officer Student	USNPGS
Petroleum Administration and Management	880	1 yr.	S.M.U.	Senior Officer Student	JAG
Petroleum Engineering (CEC)	630	1 yr.	U. of Texas	CO, NROTC	BUDOCKS
		1 yr.	industry		
Petroleum Management	811	16 mos.	U. of Kansas	CO, NROTC	BUSANDA
Political Science	680	2 yrs.	Fletcher School of Law and Diplomacy, Tufts	CO, NROTC	USNPGS
			Stanford	CO, NROTC	USNPGS
Procurement Management	815	1 yr.	U. of Mich.	CO, NROTC	BUSANDA
Public Relations	920	1 yr.	Boston U.	CO, NROTC, Harvard	CHINFO
Religion	970	9 mos.	Various		Chief of Chaplains
Retailing	830	1 yr.	Michigan State	Senior Officer Student	BUSANDA
Subsistence Technology	860	1 yr.	Mich. State	Senior Officer Student	BUSANDA
Systems Inventory Management	819	2 yrs.	Harvard	CO, NROTC	BUSANDA
Textile Technology	580	18 mos.	N. Car. State	Senior Officer Student	BUSANDA
Transportation Management	813	1 yr.	Mich. State	Senior Officer Student	BUSANDA

CURRICULA AT OTHER UNIVERSITIES

The curricula listed in this section are conducted entirely at civilian educational institutions. Quotas for enrollment must be approved by the Chief of Naval Personnel. The table indicates the duration of each curriculum, the location, and the curricular supervisory control authority as set forth in BUPERS INSTRUCTION 1520.50A. Administration of officer students in connection with educational matters is exercised by the Superintendent, U. S. Naval Postgraduate School, through the Commanding Officer, NROTC Unit, or through the Senior Officer Student at those institutions where no NROTC Unit is established.

The information on courses is taken from college catalogues, but is subject to change from year to year. Changes depend on scheduling problems at the educational institutions and on the academic backgrounds of students. Further detailed information can be obtained from the catalogue of the institution concerned, or by writing to the institution.

BUSINESS ADMINISTRATION CURRICULUM NUMBER 810

At Harvard University

OBJECTIVE—To give emphasis to the following areas of study: (1) recognition of problems, (2) realistic administrative follow-through on decisions, (3) an understanding and realistic handling of human relations, (4) administrative powers in general, (5) the relationship of business to the government and to the public welfare, (6) the integration of business functions, and (7) the point of view of the Chief Executive and the directors responsible for over-all operations so as to give the student an effective start in the development of his managerial skills and an appreciation of the responsibilities of a business administrator.

Course length: Two years

Degree attainable: Master of Business Administration

Typical Curriculum:

First Year (All courses required)

Administrative Practices
Business Responsibilities in the American Society
Control
Finance
Marketing
Production
Written Analysis of Cases

Second Year (10 half-year courses required)

Business Policy (Required)
Courses in General Business Management
Courses in Industrial and Financial Accounting
Courses in Production/Manufacturing
Courses in Finance/Investment
Courses in Advanced/International Economics
Courses in Personnel Administration/Human Relations
Courses in Marketing/Sales/Merchandising
Courses in Transportation
Courses in Military Management
Courses in Taxation
Courses in Foreign Operations
Courses in Probability and Statistics for Business Decisions
Courses in Industrial Procurement

At Stanford University

OBJECTIVE—To give the student a foundation in the following areas: (1) the external environment of the commercial firm, (2) the internal and organizational environment of the firm, (3) quantitative methods and tools of control, and (4) the management of major functions; to give the student an opportunity to apply the knowledge, skills, and attitudes acquired to the solution of action-oriented problems involving the entire commercial enterprise.

Course length: Two years

Degree attainable: Master of Business Administration

Typical Curriculum:

Required—First Year

Business Economics
Management Accounting
Business Statistics
Business Organization and Management
Business Finance
Marketing Management
Psychological Aspects of Business
Manufacturing I
Human Elements in Business
Legal Process in Business
Employment Relationships

Required—Second Year

Manufacturing II
Business Policy Formulation and Administration

Electives—Second Year

Courses in Industrial and Financial Accounting, Audit, Comptrollership
Courses in Production/Manufacturing
Courses in Finance/Investment/Banking
Courses in Personnel Administration/Industrial Relations
Courses in Marketing/Sales
Courses in Transportation
Courses in Insurance/Risk Management
Courses in Advanced Economics/International Trade
Courses in Research/Small Business Management
Courses in Business Information Systems Data Processing
Courses in Purchasing

CIVIL ENGINEERING (ADVANCED) CURRICULUM NUMBER 470

At: Georgia Institute of Technology
Massachusetts Institute of Technology
Princeton University
Purdue University
Rensselaer Polytechnic Institute
Stanford University
Texas A&M
Tulane University
University of California (Berkeley)
University of Colorado
University of Illinois
University of Michigan
University of Minnesota
University of Washington

OBJECTIVE—To educate officers for civil engineering duties. Options are available in all major fields of civil engineering. Typical options are: construction engineering, structures, soil mechanics, sanitary engineering, waterfront facilities, facilities planning, and civil engineering administration. Officers without previous civil engineering education would undertake a two-year curriculum; officers holding a Bachelor of Civil Engineering degree would undertake a one-year curriculum. This program is to qualify line officers (1100) for civil engineering duties and to provide advanced education for Civil Engineering Corps officers (5100).

Course length: One to two years

Degree attainable: Master of Science in Civil Engineering

Typical Curriculum: (For two-year Structures Option)

First Year:

Contracts and Specifications
Structural Analysis I and II
Reinforced Concrete I and II
Hydraulics
Mechanical Behavior of Materials I
Mathematics
Highway and Airport Engineering
Digital Computation Methods
Building Construction
Structural Design
Structural Mechanics

Second Year:

Advanced Mathematics
Water Supply and Sewerage
Indeterminate Structures
Prestressed Concrete
Analytical Solution of Structural Problems
Long Span Structures
Construction Methods and Estimates
Limit Design of Steel Structures
Structural Analysis for Terminal Loadings
Advanced Indeterminate Structures
Thesis

ELECTRICAL ENGINEERING (CEC) CURRICULUM NUMBER 471

At University of Michigan

OBJECTIVE—To provide advanced education for selected CEC officers in electrical engineering with emphasis on power plants and electrical utility distribution.

Course length: 15-24 months

Degree attainable: Master of Science in Electrical Engineering

ENGINEERING ELECTRONICS (CEC)

At University of Michigan

OBJECTIVE—To provide advanced education for selected CEC officers in the field of electronics with options in communication engineering, computer engineering, engineering systems and design, electromagnetic field theory, and microwave engineering.

Course length: 12 to 18 months

Degree attainable: Master of Science in Engineering Electronics

FINANCIAL MANAGEMENT CURRICULUM NUMBER 812

At George Washington University

OBJECTIVE—To develop in officers of mature judgment and a broad background of professional experience the ability to interpret and analyze operational statistics for the purpose of developing standards of performance; to provide a periodic review of operations in order to denote areas of management which are not meeting standards; to review budget estimates; and to plan programs for the improvement of management economy and efficiency through better organization, administration and procedures and better utilization of manpower, materials, facilities, funds and time. The course is designed to give graduates a working knowledge of managerial controls adequate for assignment to financial management duties as a normal preparation for command and executive billets in the shore establishment and leads to degree Master of Business Administration.

Course length: One year

Degree attainable: Master of Science in Business Administration

Typical Curriculum:

Undergraduate Courses:

General Accounting
Management Communication
Industrial and Governmental Economics
Statistical Decision Making

Graduate Courses:

Cost Accounting
Managerial Accounting
Internal Control and Audit

Financial Management
Seminar in Marketing
Management Engineering
Business Organization and Management
Reading and Conference in Financial Management
Human Relations in Business
Research Seminar in Comptrollership
Research Seminar
Governmental Budgeting

GEODESY
CURRICULUM NUMBER 475

At Ohio State University

OBJECTIVE—To prepare officers for assignment to duties at the Oceanographic Office, on geodetic survey expeditions, and on fleet staffs. The curriculum presents a fundamental theoretical knowledge of geodesy, cartography, and photogrammetry, particularly as applied to hydrographic surveying and the compilation and production of charts and maps.

Course length: Two years

Degree attainable: Master of Science in Geodesy

INTERNATIONAL RELATIONS
CURRICULUM NUMBER 671

At: American University
University of California (Berkeley)
Harvard University

OBJECTIVE—To provide a broad understanding of the forces and factors in international relations to equip officers to meet responsibilities involving knowledge of the international situation, including awareness of the role of sea power in world affairs.

Course length: One year

Degree attainable: Master's Degree

LAW
CURRICULUM NUMBER 881

(Army Judge Advocate Officers Advanced Course)

At University of Virginia

OBJECTIVE—To prepare more experienced Law Specialists (1620) for advanced staff responsibilities in the various legal fields. The course encompasses all branches of military law with emphasis on the administration of the Uniform Code of Military Justice, military affairs, civil affairs arising out of the operation of or litigation of military law, military reservations, international law including the laws of war, procurement and contract law, and legal assistance to military personnel.

Course length: Nine months

MANAGEMENT AND INDUSTRIAL ENGINEERING
CURRICULUM NUMBER 540

At Rensselaer Polytechnic Institute

OBJECTIVE—To prepare selected officers for managerial and industrial engineering billets in the Navy's industrial organization. The curriculum majors in industrial engineering and its application to managerial problems.

Course length: One year

Degree attainable: Master of Science in Management Engineering

Typical Curriculum:

Summer:
Review of Quantitative Methods
Statistical Methods
Law in Management and Engineering
Data Processing

Fall:
Cost Finding and Control
Analytical Methods in Management
New Product Problems
Production Planning
Industrial Relations

Spring:
Administrative Practice and Behavior
Organization Planning and Development
Financial Planning and Control
Seminar in Management
Production Control (Elective)
Management or Marketing (Elective)

MECHANICAL ENGINEERING (CEC)
CURRICULUM NUMBER 473

At Rensselaer Polytechnic Institute

OBJECTIVE—To provide advanced education for selected CEC officers in mechanical engineering with emphasis on power plants, heating and ventilation.

Course length: One year

Degree attainable: Master of Science in Mechanical Engineering

METALLURGICAL ENGINEERING
CURRICULUM NUMBER 640

At Carnegie Institute of Technology

OBJECTIVE—To obtain the maximum possible metallurgical background in a short program designed specifically for the graduate of the Naval Construction and Engineering Curriculum.

Course length: Nine months

Degree attainable: Bachelor of Science in Metallurgy

NAVAL CONSTRUCTION AND ENGINEERING CURRICULUM NUMBER 510

At Massachusetts Institute of Technology
Webb Institute of Naval Architecture

OBJECTIVE—To qualify selected officers for duty assignments in the fields of naval construction and marine engineering. The curricula are arranged to provide a broad capability in naval architecture and an exceptional capability in one option or specialty. Options are available in the following areas: hull design and construction, marine electrical engineering, electronics engineering and ship propulsion engineering. Selection of options is made after completion of the first summer term. Exceptional students are encouraged to pursue advanced work at the doctoral level. Successful completion of this curriculum leads to "Engineering Duty" designation (1400).

Course length: Three years

Degree attainable: Master of Science in Naval Architecture and Marine Engineering and the Degree of Naval Engineer

Typical Curriculum at M.I.T.:
(Hull Design and Construction Option)

First Summer:

Strength of Materials and Dynamics
Applied Hydrostatics
Review of Mathematics

First Year:

Structural Mechanics
Fluid Mechanics
Thermodynamics
History of Naval Ships
Advanced Calculus for Engineers
Naval Structural Engineering
Heat Transfer
Introduction to Nuclear Physics
Principles of Naval Architecture
Naval Ship General Arrangements I
Introduction to Probability and Random Variables

Second Summer:

Digital Computer Program Systems
Advanced Calculus for Engineers

Second Year:

Advanced Hydromechanics I and II
Properties of Metals
Naval Structural Theory I and II
Naval Ship Propulsion I
Mechanical Vibration
Naval Ship General Arrangements II
Naval Structural Analysis
Advanced Mechanics
Properties of Metals
Electives: Experimental Hydrodynamics
Naval Structural Design I
Naval Electrical Engineering

Third Summer:

Industrial Tour

Third Year:

Advanced Structural Mechanics
Experimental Stress Analysis
Principles of Ship Design
Principles of Naval Ship Design
Hydroacoustics
Naval Ship Propulsion II
Electives: Naval Structural Design II
Buckling of Structures
Plasticity
Thesis

NUCLEAR ENGINEERING (ADVANCED) CURRICULUM NUMBER 520

At Massachusetts Institute of Technology

OBJECTIVE—To qualify officers for the technical direction of nuclear power development in the Navy. Graduates of this program can normally expect to be assigned duties within the nuclear power development program under the direction of the Bureau of Ships.

Course length: 14 months

Degree attainable: Master of Science

NUCLEAR POWER ENGINEERING (CEC) CURRICULUM NUMBER 572

At: University of California (Berkeley)
University of Michigan

OBJECTIVE—To provide education for selected CEC officers in nuclear power engineering. Graduates of this curriculum will normally be assigned duties in the shore nuclear power program under the technical direction of the Bureau of Yards and Docks.

Course length: 15 to 20 months

Degree attainable: Master of Science

OCEANOGRAPHY CURRICULUM NUMBER 440

At: University of Washington
Texas A&M College
University of Miami (Fla.)
University of California (San Diego)

OBJECTIVE—To prepare officers for assignment to billets requiring comprehensive theoretical and practical foundation in the various aspects of oceanography. Students may specialize in physical, biological, chemical or geological oceanography. Prerequisites for this program include college general chemistry and general physics, and mathematics through differential and integral calculus.

Course length: Two years

Degree attainable: Master of Science in Oceanography

PETROLEUM ADMINISTRATION AND MANAGEMENT
(Gas, Oil and Water Rights)
CURRICULUM NUMBER 880

At Southern Methodist University

OBJECTIVE—To provide Law Specialists (1620) with a study of government regulations in oil and gas law taxation problems, and special research and study of the evolution of law concerning water rights, current law affecting these rights, and technical problems attendant thereto so as to prepare them for assignment to billets concerned with the administration and management of the Naval Petroleum and Oil Shale Reserves and with the special problems in the field of water rights.

Course length: One year

Degree attainable: Master of Laws in Oil and Gas

PETROLEUM ENGINEERING (CEC)
CURRICULUM NUMBER 630

At University of Texas
and in the petroleum industry

OBJECTIVE—To prepare selected CEC officers for assignments to duty involving the administration and operations of Naval Petroleum and Oil Shale Reserves. The curriculum provides the student with a knowledge of petroleum development and production procedures, geology, petroleum economics and reservoir engineering.

Course length: One year of academic work followed by up to one year in the field with a major oil company

Degree attainable: Master of Science in Petroleum Engineering

PETROLEUM MANAGEMENT
CURRICULUM NUMBER 811

At University of Kansas

OBJECTIVE—To provide officers of the Supply Corps with graduate level education in the functional proficiency field of petroleum management and administration.

Course length: Sixteen months
Degree attainable: Master of Science
Typical Curriculum:

Fall:

Financial Accounting and Control I
Personnel Management
Material and Energy
Development of Oil and Gas Lands
Theoretical Principles of Petroleum Production

Spring:

Financial Accounting and Control II
Statistical Methods
Legal Aspects of Business
Field Practice in Natural Gas
Appraisal of Oil and Gas Properties

Summer:

Special Problems in Business Administration
Chemical Engineer Research

POLITICAL SCIENCE
CURRICULUM NUMBER 680

At: The Fletcher School of Law and Diplomacy, Tufts University
Stanford University

OBJECTIVE—To equip a limited number of intellectually mature officers with a broad professional background in international relations in order that they may provide professional advice and assistance in the formulation and execution of national policy. Studies should be specifically directed toward obtaining sound knowledge and understanding in:

(1) The theory of international politics, economics, law, and U.S. diplomatic history.

(2) The politics, geography and history of one of the following regions of the world: Europe, Asia, Africa, Western Hemisphere.

(3) The history, role and importance of world-wide and regional international organizations.

(4) Development and execution of U.S. political, military and economic policy as it pertains to U.S. foreign relations.

Course length: Two years

Degree attainable: Master of Arts

PROCUREMENT MANAGEMENT
CURRICULUM NUMBER 815

At University of Michigan

OBJECTIVE—To provide officers of the Supply Corps with graduate level education in the field of military and commercial procurement:

Course length: One year

Degree attainable: Master of Business Administration

PUBLIC RELATIONS
CURRICULUM NUMBER 920

At Boston University

OBJECTIVE—To provide advanced qualifications of officers in the field of public relations. Officers selected for this program must have previous education or experience in public information and public relations. The curriculum will be made up from regular course offerings of the university and will be based on an officer student's background and particular interest within the curricular area.

Course length: One year

Degree attainable: Master of Arts in Public Relations

RELIGION
CURRICULUM NUMBER 570

At: Harvard University
Yale University
Catholic University
University of Chicago
University of Notre Dame
Fordham University
Union Theological Seminary

OBJECTIVE—To broaden the education of officer students in such fields as psychology, theology, homiletics, and counseling, hospital ministry and education.

Course length: 9 months

RETAILING
CURRICULUM NUMBER 830

At Michigan State University

OBJECTIVE—To provide officers of the Supply Corps with graduate level education in the functional proficiency field of retailing. Emphasis is placed on consumer markets, sales promotion, merchandise and merchandising, and the management functions associated therewith.

Course length: One year
Degree attainable: Master of Business Administration

SUBSISTENCE TECHNOLOGY
CURRICULUM NUMBER 860

At Michigan State University

OBJECTIVES—To provide officers of the Supply Corps with graduate level education in the field of food management.
Course length: One year
Degree attainable: Master of Business Administration

SYSTEMS INVENTORY MANAGEMENT
CURRICULUM NUMBER 819

At Harvard University

OBJECTIVE—To provide officers of the Supply Corps with a well-grounded education at the graduate level in the scientific methods of inventory management.

Course length: Two years
Degree attainable: Master of Business Administration
Typical Curriculum:

First Year: (Required)
Administrative Practices
Control
Finance
The Manager and The American Economy
Marketing
Production
Written Analysis of Cases

Second Year: (Required)
Management Information Systems
Business Logistics
Financial Accounting I and II
Seminar in Military Marketing and Project Management

Second Year: (Electives) (Four to be selected)
Cost Administration
Industrial Procurement
Managing Technological Change
Planning and Controlling Production
*Analysis of Quantitative Data I and II
*Probability and Statistics for Business Decisions I and II
*Topics in Operations Analysis I and II
*Management Economics
*Prerequisite—Mathematics through Differential Calculus

TEXTILE TECHNOLOGY
CURRICULUM NUMBER 580

At North Carolina State College

OBJECTIVE—To provide officers of the Supply Corps with graduate level education in the functional proficiency field of textile management.

Course length: 18 months
Degree attainable: Master of Textile Technology
Typical Curriculum:
Technology Seminar
Textile Testing II
Textile Quality Control
Complex Woven Structures
Fabric Analytics and Characteristics
Yarn Manufacture
Synthetics IV
Fabric Development and Construction
Principles of Accounting
Introduction to Production Costs
Management Policy and Decision Making
Management of Industrial Relations

TRANSPORTATION MANAGEMENT
CURRICULUM NUMBER 813

At Michigan State University

OBJECTIVE—To provide officers of the Supply Corps with graduate level education in the functional proficiency field of transportation management.

Course length: One year
Degree attainable: Master of Business Administration
Typical Curriculum:
Basic Accounting II
Financial Management
Basic Marketing
Basic Statistics I
Accounting for Financial and Profit Management II
Problems in Business Economics
Basic Statistics II
Transportation Policy
Accounting for Financial and Profit Management III
Human Problems in Administration
Social Problems in Administration
Marketing Management
Transportation Seminar

ACADEMIC DEPARTMENTS
and
COURSE DESCRIPTIONS

DEPARTMENT OF AERONAUTICS

Richard William Bell, Professor of Aeronautics; Chairman (1951),* A.B., Oberlin College, 1939; Ae.E., California Institute of Technology, 1941; Ph.D., 1958.

Eric John Andrews, Professor of Aeronautics (1959): Honors B.S., Aero.Eng., Univ. of London, 1936.

Wendell Marios Coates, Fellow, Professor of Aeronautics (1931); A.B., Williams College, 1919; M.S., Univ. of Michigan, 1923; D.Sc., 1929.

Nicholas Cosmo Gallinaro, Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Aeronautics (1963); B.S., Tufts Univ., 1962.

Theodore Henry Gawain, Professor of Aeronautics (1951); B.S., Univ. of Pennsylvania, 1940; D.Sc., Massachusetts Institute of Technology, 1944.

Ulrich Haupt, Associate Professor of Aeronautics (1954); Dipl. Ing., Institute of Technology, Darmstadt, 1934.

George Judson Higgins, Professor of Aeronautics (1942); B.S., in Eng. (AeE), Univ. of Michigan, 1923; AeE., 1934.

Charles Horace Kahr, Jr., Professor of Aeronautics (1947); B.S., Univ. of Michigan, 1944; M.S., 1945.

Henry Lebrecht Kohler, Professor of Aeronautics (1943); B.S. in M.E., Univ. of Illinois, 1929; M.S. in M.E., Yale Univ., 1930; M.E., 1931.

Donald Merrill Layton, Commander, U.S. Navy; Instructor in Aeronautics (1965); B.S., U.S. Naval Academy, 1945; B.S. in A.E., U.S. Naval Postgraduate School, 1953; M.S. in A.E., Princeton Univ., 1954.

Donald Wright Mackenzie, Lieutenant, U.S. Naval Reserve; Instructor in Aeronautics (1963); B.M.E., Cornell Univ., 1953; M.S., Lehigh Univ., 1957.

James Avery Miller, Associate Professor of Aeronautics (1963); B.S. in M.E., Stanford Univ., 1955; M.S. in M.E., Stanford Univ., 1957; Ph.D., Illinois Institute of Technology, 1963.

Roy Earl Reichenbach, Associate Professor of Aeronautics (1962); B.M.E., Ohio State Univ., 1956; M.S., 1956; Ph.D., California Institute of Technology, 1960.

Louis Vincent Schmidt, Associate Professor of Aeronautics (1964); B.S., California Institute of Technology, 1946; M.S., 1948; Ae.E., 1950; Ph.D., 1963.

James Herbert Starnes, Jr., Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Aeronautics (1963); B.S., Georgia Institute of Technology, 1961; M.S., Georgia Institute of Technology, 1963.

Alfred Francis Vachris, Jr., Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Aeronautics (1963); B.S., Univ. of Notre Dame, 1962; M.S., Polytechnic Institute of Brooklyn, 1963.

Michael Hans Vavra, Professor of Aeronautics (1947); Dipl. Ing., Swiss Federal Institute of Technology, 1934; Ph.D., Univ. of Vienna, 1958.

Helmut Ernst Weber, Associate Professor of Aeronautics (1965); S.B. and S.M. in M.E., Massachusetts Institute of Technology, 1951; Sc.D., 1955.

*The year of joining the Postgraduate faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN AERONAUTICAL ENGINEERING

The following is a summary of the minimum academic requirements for the award of these degrees as determined by the Aeronautics Department. Any curriculum toward these degrees must also be consistent with the general minimum requirements as determined by the Academic Council.

BACHELOR OF SCIENCE IN AERONAUTICAL ENGINEERING

This degree normally requires a minimum of 96 term hours of upper division courses in residence at the Postgraduate School (unless reduced by validated advanced credit) of which at least 70 term hours are in aeronautics courses. The following requirements must be met:

Subject:	*Approximate Term Hours*
Aerodynamics and aircraft dynamics	21
Solid Mechanics and structural design	21
Thermodyanimcs and propulsion	18
Methods for Digital and Analog Computers	4
Basic Electric Fields and Circuits	8

Every candidate's undergraduate record, at the Naval Postgraduate School, or as validated from other institutions, must include:

a. Basic mathematics through differential equations, including adequate preparatory coverage.

b. Basic coverage in physics and chemistry to at least 12 term hours or the equivalent in each field.

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

This degree requires a minimum of 56 graduate level term hours in residence at the Postgraduate School (unless reduced by validated advanced credit) of which at least 36 graduate level hours are to be in aeronautics courses. These requirements include term hours allotted to research. Not less than one-half of the remainder of the stated number required must be taken in A level courses. The following specific requirements will be met:

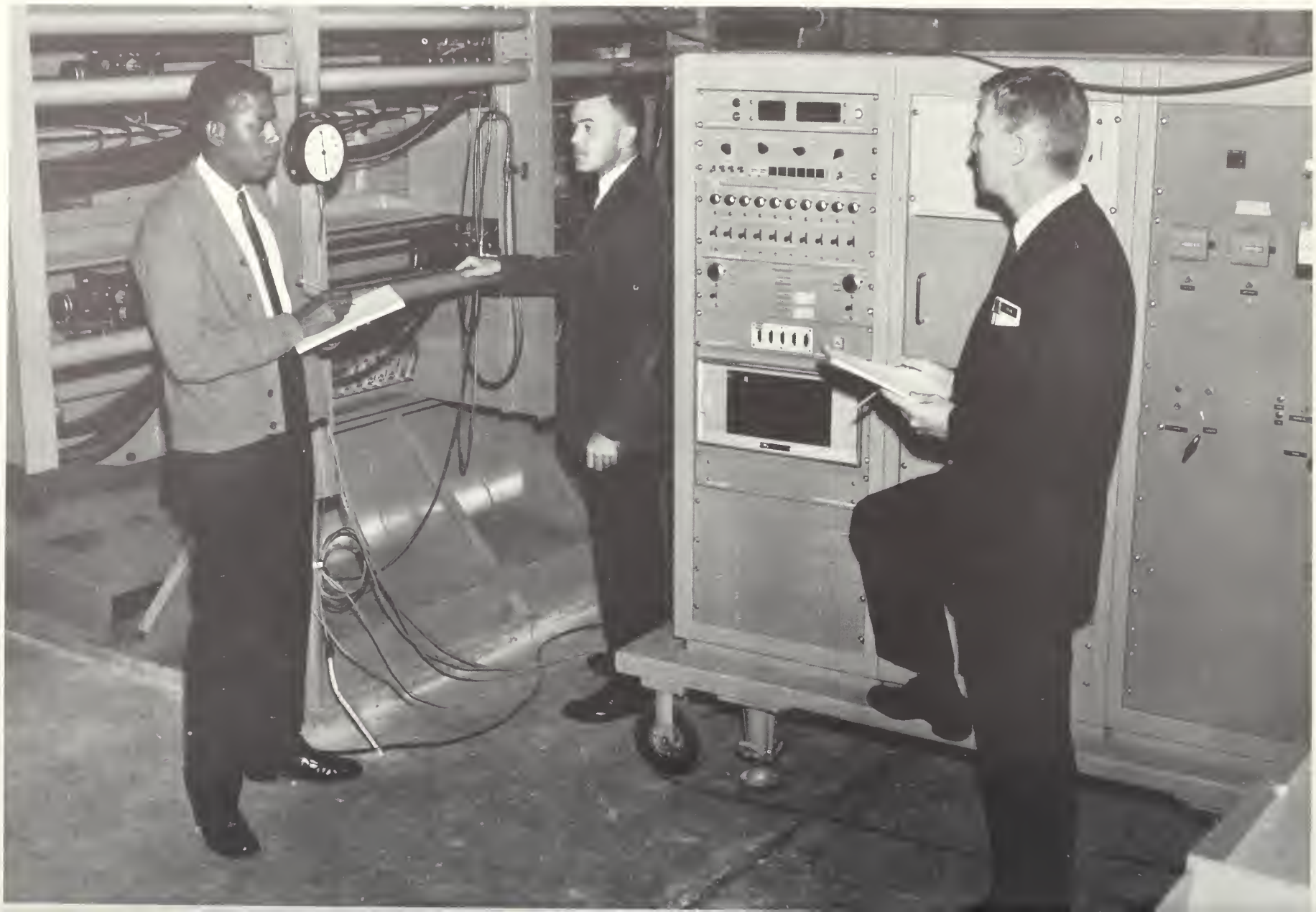
a. *Propulsion:* at least one graduate lecture course in the Ae 400 series.

b. *Gas dynamics:* at least a two-term lecture sequence in the Ae 500 series.

c. *Structures:* at least a two-term lecture sequence in the Ae 600 series.

d. *Systems engineering:* at least one lecture course in the Ae 700 series.

e. *Computers:* unless previously satisfied, one course in the use of digital analog computers.



f. *Options:* specialization in one of the available options such as 1) Flight Systems; 2) Propulsion; 3) Structures; 4) Flight test and evaluation; 5) Gas dynamics; or 6) Other recognized specialty in aeronautics.

g. *Research and thesis:* at least 10, but not more than 15, graduate term hours in Ae 000 (Research), plus an acceptable thesis (this requirement may be waived upon recommendation of the Chairman, Aeronautics Department).

AERONAUTICAL ENGINEER

This degree requires a minimum of 115 graduate level term hours in residence at the Postgraduate School (unless reduced by validated advanced credit) of which at least 65 graduate level hours are to be in aeronautics courses. These requirements include term hours allotted to research. Not less than one-half of the remainder of the stated number required must be taken in A level courses. Specific requirements to be met are the same as outlined in items a. through f. of the M.S. program. Additional requirements are:

a. *Major:* at least 3 additional graduate aeronautics lecture courses of the major option, and 2 additional graduate aeronautics lecture courses in support of that option; final coverage in the option to be approved by the Chairman, Aeronautics Department.

b. *Research and thesis:* at least 15 but not more than 20 graduate term hours in Ae 000 (Research), plus an acceptable thesis.

AERONAUTICS

Ae 001E AERONAUTICAL LECTURE SERIES (0-1). Lectures on general aeronautical engineering subjects by prominent authorities from the Navy Department, research laboratories and the industry.

Ae 010E AERONAUTICAL SEMINAR (0-1). Discussion of aeronautical development and reports on progress in research by faculty and students.

Ae 104C AERODYNAMICS (3-2). Atmospheric properties. Flow kinematics and dynamics. Air speed measurement. Dimensional analysis, aerodynamic coefficients, Mach and Reynolds numbers. Viscosity, boundary layers, separation, form and friction drag. Circulation, lift and the Kutta-Joukowsky relation, downwash, induced drag. Aerodynamic center. Camber, thickness, planform effects. High lift devices, spoilers. TEXTS: Dommasch, Sherby and Connolly, *Airplane Aerodynamics;* Hurt, *Aerodynamics for Naval Aviators.* PREREQUISITE: Validated credit in mathematics and mechanics.

Ae 105C AIRCRAFT PERFORMANCE (3-2). The flight vehicle and its components: lift, drag and interference effects. Wing stall. Parasite drag. The drag polar. Mach and Reynolds number effects. The propeller. Aircraft propulsion. Static performance: power required and available; level flight, climbing and diving flight; ceilings. Range and endurance. TEXTS: Same as Ae 104C. PREREQUISITE: Ae 104C.

Ae 106C AIRCRAFT DYNAMICS I (3-2). Special performance problems: landing, take-off, maneuvers. Dynamic performance methods. Static longitudinal stability and control: theory and design of control surfaces; stick-fixed and stick-free stability, static margin, neutral points; control effectiveness, airplane trim, C.G. limits; empennage and other component effectiveness. Stick force characteristics; tab and bungee effects. TEXTS: Same as AE 104C. PREREQUISITE: Ae 105C.

Ae 107B AIRCRAFT DYNAMICS II (3-2). Static longitudinal stability and control: maneuver points, stick force per g. Static lateral and directional stability and control; adverse yaw, asymmetric power, rudder lock, dihedral effect, rolling velocity. Propulsion effects. Euler equations of motion, longitudinal dynamics; stability derivatives, characteristic transients, control response, control-free and special problems. TEXTS: Same as Ae 104C, plus Etkin, *Dynamics of Flight.* PREREQUISITE: Ae 106C.

Ae 108B AIRCRAFT DYNAMICS III (3-2). Lateral and directional dynamics, characteristic transients, control response and effects of free controls. Vehicle configurations with coupled dynamic modes. Aeroelastic effects. Compressibility effects. Special problems. Principles of automatic control. TEXTS: Same as Ae 107B plus USNAVPGSCOL notes. PREREQUISITE: Ae 107B.

Ae 109C AERODYNAMICS LABORATORY (0-3). The subsonic windtunnel, its basic equipment, instrumentation, and use for engineering experimentation. Methods of data analysis and reporting. TEXT: Pope, *Wind Tunnel Testing,* 2d ed. PREREQUISITE: Ae 104C.

Ae 110C AERODYNAMICS LABORATORY II (0-3). Continuation of Ae 109C. Wind tunnel experiments to determine forces and moments on complete model flight vehicles and components. PREREQUISITE: Ae 107B, can be taken simultaneously.

Ae 151C FLIGHT TEST EVALUATION I (2-0). Relative to flight test methods and procedures, a lecture program encompassing instrument calibrations, measurement of flight speed, cruising performance, stall tests, etc. Definition of requirements in flight test report writing. TEXTS: Dommasch, Sherby and Connolly, *Airplane Aerodynamics;* NATC Patuxent, Flight Test Manual; NAV AERO Publications.

Ae 152B FLIGHT TEST EVALUATION II (2-0). Relative to flight test methods and procedures, a lecture program encompassing climb performance, energy height concept, drag measurement, static and maneuvering longitudinal stability. TEXTS: Same as Ae 151C.

Ae 153B FLIGHT TEST EVALUATION III (2-0). Relative to flight test methods and procedures, a lecture program encompassing longitudinal and lateral/directional dynamic stability; time vector determination of derivatives. TEXTS: Same as Ae 151C.

Ae 161C FLIGHT TEST EVALUATION LABORATORY I (0-4). Flight program accompanying Ae 151C. Test flying in naval aircraft by aviator students primarily for level flight evaluation.

Ae 162B FLIGHT TEST EVALUATION LABORATORY II (0-4). Flight program accompanying Ae 152B. Test flying in naval aircraft by aviator students primarily for climb performance and static and maneuvering longitudinal stability.

Ae 163B FLIGHT TEST EVALUATION LABORATORY II (0-4). Flight program accompanying Ae 153B. Test fly ing in naval aircraft by aviator students primarily for dynamic stability and derivative measurement.

Ae 171A VECTOR MECHANICS OF FLUID FLOW (3-2). Edited to the interests of ordnance curricula. Coverage similar to Ae 511A. TEXT: Same as Ae 511A. PREREQUISITES: Same as Ae 511A.

Ae 172A LAMINAR AND TURBULENT FLOW (3-2). Coverage similar to Ae 512A, but edited to the interests of ordnance curricula. TEXT: Same as Ae 512A. PREREQUISITE: Ae 171A.

Ae 173A COMPRESSIBLE FLOW (4-0). Essentially the coverage in Ae 513A, edited to the interests of ordnance curricula. TEXTS: Same as Ae 513A. PREREQUISITE: Ae 171A.

Ae 174A COMPRESSIBLE FLOW II (3-0). Edited to the interests of ordnance curricula, with coverage similar to Ae 514A. TEXTS: Same as Ae 514A. PREREQUISITE: Ae 172A and Ae 173A. Also Ae 519A to be taken concurrently.

Ae 175A MISSILE DYNAMICS (3-2). Generalized force fields on flight vehicles, in continuation of this sequence. Equations of motion, trim, performance, range, static and dynamic stability, controllability, practical design problems and analysis of a particular missile. TEXT: Same as Ae 107B. PREREQUISITE: Ae 173A.

Ae 204C STRUCTURAL MECHANICS I (3-2). Applied mechanics of rigid bodies for application to structures of flight vehicles: Force systems, truss analysis, section properties, shear and moment diagrams. Hooke's law and deformations. Problem work and laboratory tests supplement theory. TEXTS: Beer and Johnston, *Statics;* Timoshenko, *Strength of Materials, Vol. I.* PREREQUISITE: Engineering Mechanics (Statics).

Ae 205C STRUCTURAL MECHANICS II (3-2). State of stress at a point, stress-strain relations, bending and shear stresses, energy principles, bending deflections. Problem work and laboratory tests supplement theory. TEXTS: Timoshenko, *Strength of Materials, Vol I;* Shanley, *Strength of Materials.* PREREQUISITE: Ae 204C.

Ae 206C STRUCTURAL COMPONENTS I (3-2). Extended discussion of statically indeterminate systems such as beams, frames, trusses. Thermal effects. Matrix formulation of structures problems. Curved bars. Problem work and laboratory tests supplement theory. TEXTS: Shanley, *Strength of Materials;* Peery, *Aircraft Structures.* PREREQUISITE: Ae 205C.

Ae 207C STRUCTURAL COMPONENTS II (3-2). Analysis of thin-walled structures typical of flight vehicles. Unsymmetrical bending, shear flow in open and closed sections, diagonal tension field webs, torsion in non-cylindrical sections, membrane analogy. Problem work and laboratory tests supplement theory. TEXTS: Shanley, *Strength of Materials;* Peery, *Aircraft Structures.* PREREQUISITE: Ae 206C.

Ae 209C STRUCTURAL LABORATORY (0-3). Fundamentals of static and dynamic strain measurement. Electrical resistance gages, semiconductor gages, optical gages, voltage-to-frequency converters, oscillographs. Brittle lacquer coating. Evaluation of strain measurements. TEXTS: Perry and Lissner, *Strain Gage Primer;* Notes. PREREQUISITE: Ae 205C.

Ae 214A STRUCTURAL COMPONENTS III (4-0). Columns and beam-columns. Lateral and torsional buckling of beams. Axially symmetrical plates. General theory of plates; moments, stresses, curvatures, equilibrium. TEXTS: Sechler, *Elasticity in Engineering.* PREREQUISITE: Ae 207C.

Ae 215A ADVANCED STRUCTURES (4-0). Elasticity equations, energy methods. Matrix formulations in structural analysis, built up wing applications. Selected topics in vibrations, stability, plasticity. TEXTS: Same as Ae 214A, others depend upon topics. PREREQUISITE: Ac 214A.

Ae 221B STRUCTURAL PERFORMANCE (2-2). Application of fundamental testing techniques from Ae 209C to full-scale wings. Evaluation of stress distribution in various structures. Fundamentals of photo-elasticity and photo-elastic coating. TEXT: Perry and Lissner, *Strain Gage Primer;* Notes. PREREQUISITE: Ae 209C.

Ae 231B STRUCTURAL DESIGN I (2-2). Design and analysis of a flight vehicle. Preliminary layout, three-view drawing, weight and balance. Basic aerodynamic characteristics and performance. Strength and rigidity requirements, V-n diagram, resulting loads, shear and moment diagrams. Structural design considerations from the viewpoints of strength, fatigue, production and optimization. TEXTS: Specifications MIL-A-8860 to 8870 (ASG); MIL-HDBK-5; Peery, *Aircraft Structures;* Corning, *Supersonic and Subsonic Airplane Design;* Bruhn, *Analysis and Design of Flight Vehicle Structures.* PREREQUISITE: Ae 207C.

Ae 232B STRUCTURAL DESIGN II (2-2). A continuation of Ae 231B. Detail analysis of a major structural component, calculation of loads from a computer program, determination of allowable stresses for sheets and sheet-stringer combinations. Stresses in the plastic range. Consideration of typical structures and structural trends in airplanes, missiles, launchers and spacecraft. TEXTS: Same as Ae 231B, plus additional selected publications. PREREQUISITE: Ae 231B.

Ae 236B STRUCTURAL DESIGN (3-2). Detail methods of airplane or missile design and analysis. Preliminary layout; three view drawing; weight and balance, aerodynamic characteristics and basic performance; design criteria; inertia loads, shear and moment curves; detail structural design and stress analysis of major component. TEXTS: Peery, *Aircraft Structures;* Bonney, *Principles of Guided Missile Design;* Chin, *Missile Configuration Design;* Bruhn, Analysis and Design of Flight Vehicle Structures. PREREQUISITE: Ae 207C.

Ae 304C FLIGHT KINEMATICS (2-2). Kinematics of the vehicle in air or space; coordinate systems and transformations, Newton's laws and applications to mechanics of vehicle motion in air or space, potential fields. TEXTS: Rauscher, *Introduction to Aeronautical Dynamics;* Housner and Hudson, *Dynamics.* PREREQUISITE: Validated advanced credit in basic B.S. level mathematics and engineering.

Ae 305C FLIGHT DYNAMICS I (2-2). Dynamics of rigid bodies, stability considerations, constraints and degrees of freedom, generalized coordinates, Lagrange's equations for a particle and systems of particles. Orbits and trajectories. TEXTS: Same as Ae 304C. PREREQUISITE: Ae 304C.

Ae 306C FLIGHT DYNAMICS II (2-2). Continuation of Ae 305C. Oscillating systems, vibration modes for small motion, conservative and non-conservative systems, application of matrix algebra to eigenvalue problems. Response traits of free and forced vibrations. TEXTS: Same as Ae 304C. PREREQUISITE: Ae 305C.

Ae 307C FLIGHT DYNAMICS III (2-2). Continuation of Ae 306C. Elastic body dynamics, wave propagation; calculus of variations and simple applications, Hamilton's principle. TEXTS: Same as Ae 304C. PREREQUISITE: Ae 306C.

Ae 309C DYNAMICS LABORATORY (0-3). Conduct experiments in the fundamentals of dynamics, use of the shaker table, measure displacements and accelerations; solve systems of equations by analog computer means. PREREQUISITE: Ae 306C, or Ae 307B simultaneously.

Ae 404C THERMODYNAMICS I (3-2). Basic concepts and fundamental laws of thermal energy. TEXTS: Lee and Sears, *Thermodynamics;* Keenan and Kaye, *Gas Tables;* Keenan and Keyes, *Thermodynamic Properties of Steam.* PREREQUISITE: Earlier B.S. engineering thermodynamics.

Ae 405C THERMODYNAMICS II (3-2). Continuation of Ae 404C to include one dimensional isentropic and adiabatic compressible flow. TEXT: Same as Ae 404C. PREREQUISITE: Ae 404C.

Ae 406C THERMODYNAMICS III (3-2). An extension of Ae 405C to include combustion and heat transfer. TEXTS: Lee and Sears, *Thermodynamics;* Jacob and Hawkins, *Elements of Heat Transfer and Insulation.* PREREQUISITE: Ae 405C.

Ae 407B AIRCRAFT PROPULSION (3-2). Application of air-breathing machinery to aircraft propulsion. Performance of propellers, turbo-fan and turbojet engines and components in relation to vehicle performance. TEXT: Hesse, *Jet Propulsion,* USNPGS Notes. PREREQUISITE: Ae 406C.

Ae 408A AIRCRAFT PROPULSION II (3-2). Supersonic and Hypersonic vehicle propulsion. Ramjets and unconventional propulsion machinery. TEXT: Hesse, *Jet Propulsion;* Sutton, *Rocket Propulsion Elements;* Corliss, *Propulsion Systems For Space Flight;* USNPGS Notes. PREREQUISITE: Ae 407B.

Ae 409C AEROTHERMODYNAMICS LABORATORY (0-3).Laboratory experiments pertinent to Ae 404C and Ae 405C.

Ae 422A PERFORMANCE OF PROPULSION SYSTEMS (4-2). Application of air-breathing and rocket engines to the propulsion of manned aircraft and missiles. Theory and performance of advanced systems for space propulsion. PREREQUISITE: Ae 408A.

Ae 423A ADVANCED PROBLEMS IN PROPULSION (4-2). Selected problems investigated and reported individually by students. Subject matter varies following developments in technology. PREREQUISITE: Ae 408A.

Ae 430A PRINCIPLES OF TURBOMACHINES (3-0). General relations for flows with energy changes, relative and absolute motions: energy equations and momentum theorems. Operating principles and performances of compressors, pumps, and turbines. TEXTS: Shepherd, *Principles of Turbomachinery;* Vavra, *Aerothermodynamics.* PREREQUISITE: Ae 508A simultaneously.

Ae 431A AEROTHERMODYNAMICS OF TURBOMACHINES I (4-0). Rational course on flows of elastic fluids in turbomachines. Fundamental relations for arbitrary applications to rotating machinery of axial and centrifugal type. TEXT: Vavra, *Aerothermodynamics.* PREREQUISITE: Ae 513A.

Ae 432A AEROTHERMODYNAMICS OF TURBOMACHINES II (4-0). Continuation of Ae 431A, with special emphasis on practical design criteria for applications to jet engines, rocket motor turbo-pumps, and space power plants. TEXT: Vavra, *Aerothermodynamics.* PREREQUISITES: Ae 431A, Ae 451A.

Ae 433A ADVANCED PROPULSION SYSTEMS (4-0). Application of fluid dynamics, thermodynamics and stress analysis to propulsion systems for different flight vehicles using conventional and exotic fluids. Heat transfer elements, effects of temperature. Off-design performance, matching and control. TEXT: Vavra, *Aerothermodynamics. PREREQUISITES:* Ae 432A, Ae 452A.

Ae 434A SPACE POWER PLANTS (3-0). Power plants for propulsion and generation of electrical energy for space vehicles with chemical, nuclear, and solar heat sources and radiative heat sinks. TEXT: Corliss, *Propul-*

sion Systems for Space Flight; Kreith, *Radiation Heat Transfer;* Vavra, *Aerothermodynamics.* PREREQUISITES: Ae 440A, 460A.

Ae 440A DESIGN OF TURBOMACHINERY (4-0). Analysis and design of elements of turbomachines. Centrifugal and thermal stresses in blades and disks, vibratory analysis, critical speed, stress analysis, and modern design concepts. TEXT: USNPGS Notes. PREREQUISITES: Ae 431A, Ac 451A, Ae 430A, Ae 450A.

Ae 450A PROPULSION LABORATORY I (0-3). Course given in conjunction with Ae 430A. Measurements and analysis of flows in compression and turbines, cascade test rigs and flow channels. Performance of jet engines and rocket motors. TEXTS: Vavra, *Aerothermodynamics;* Vavra, *Compressor Test Rig.* PREREQUISITE: Same as Ae 430A.

Ae 451A PROPULSION LABORATORY II (0-3). Course given in conjunction with Ae 431A. Same coverage as Ae 450A, with special emphasis on correlation of test results with theory. TEXTS: Same as Ae 450A. PREREQUISITES: Same as Ae 431A.

Ae 452A PROPULSION LABORATORY III (0-3). Course given in conjunction with and to supplement Ae 432A. Determination of off-design performance of turbomachines. Three-dimensional flow phenomena. TEXT: Same as Ae 432A. PREREQUISITE: Same as Ae 432A.

Ae 453A PROPULSION LABORATORY IV (0-3). Course given in conjunction with and to supplement extension of Ae 433A, with advanced methods and instrumentation. Data reduction with electronic computer. Heat transfer and control tests. TEXT: Same as Ae 433A. PREREQUISITE: Same as Ae 433A.

Ae 454A LABORATORY SEMINAR I (1-4). Advanced individual test assignments to supplement course Ae 434A. TEXT: Same as Ae 434A. PREREQUISITE: Same as Ae 434A.

Ae 455A LABORATORY SEMINAR II (1-3). Continuation of Ae 454A: Advanced assignments following developments in the problems, design, and testing of turbomachinery. TEXT: Same as Ae 440A. PREREQUISITE: Same as Ae 440A.

Ae 460A PROPULSION DESIGN LABORATORY (0-2). Course given in conjunction with Ae 440A. Test of disk and bladings in Hotspin Test Unit, evaluation of centrifugal and thermal stresses, vibration tests on electric shaker, work on critical speed test rig, bearings and seal tests. TEXT: Same as Ae 440A. PREREQUISITE: Same as Ae 440A.

Ae 471A COMBUSTION THERMODYNAMICS (3-2). Thermodynamics of combustion, quantitative evaluation of rocket propellants, phenomenological chemical kinetics. Ionization and dissociation in gases, and relaxation phenomena. TEXT: Penner, *Chemistry Problem in Jet Propulsion.* PREREQUISITE: Ae 405C.

Ae 472A AEROTHERMOCHEMISTRY (3-2). Chemical reactions in flow systems, with emphasis on the interplay between aerodynamics, physics, and chemistry. Topics include reactions during nozzle flow, diffusion flames, detonation, flame propagation, burning mechanism of solid propellants, heterogeneous combustion, and scaling of combustion devices. TEXT: Penner, *Chemistry Problem in Jet Propulsion.* PREREQUISITE: Ae 471A.

Ae 473A ADVANCED PROBLEMS IN COMBUSTION AND/OR AEROPHYSICS (3-2). Selected modern topics chosen by the professor after consultation with interested students. Possible topics include rarefied gas flows, magnetohydrodynamics, combustion of liquid fuel droplets, combustion of metals, combustion of solid propellants, supersonic combustion, and hybrid combustion. PREREQUISITE: Ae 472A.

Ae 474A ADVANCED PROBLEMS IN COMBUSTION AND/OR AEROPHYSICS (3-2). PREREQUISITE: Ae 473A.

Ae 501A HYDRO-AERO MECHANICS I (4-0). Dynamic equations for real fluids in vector and tensor form, circulation, rotational flow, potential flow, perfect fluid equations, complex variables and conformal mapping, two-dimensional airfoil theory. TEXTS: Kuethe and Schetzer, *Foundation of Aerodynamics;* Abbott and Von Doenhoff, *Theory of Wing Sections;* Instructor's Notes. PREREQUISITE: Same as Ae 511A.

Ae 502A HYDRO-AERO MECHANICS II (4-0). Continuation of Ae 501A. Laws of vortex motion, finite span wing theory, hydrodynamics of viscous fluids, pipe flow, boundary-layer, equations, Blasius' solution, Karman integral relation, turbulent boundary-layer, transition. TEXTS: Same as Ae 501A. PREREQUISITE: Ae 501A.

Ae 508A COMPRESSIBILITY (3-2). One dimensional gas dynamics; channel flow, normal and oblique shock waves, Prandtl-Meyer expansion, three dimensional flow equations; Crocco's theorem, linearized potential flow and application to airfoils and bodies of revolution, method of characteristics. TEXTS: Same as Ae 501A. PREREQUISITE: Ae 502A.

Ae 511A VECTOR MECHANICS OF FLUID FLOW (4-0). Basic equations of fluid flow in generalized vector and tensor form. Flow kinematics, stress-strain relations, Navier Stokes equations. Principles of continuity, momentum and energy in differential and integral form. Laws of vorticity, circulation and lift. Elementary two and three-dimensional potential flows. Introduction to use of complex variable. Dimensional analysis. TEXTS: Kuethe and Schetzer, *Foundations of Aerodynamics;* Vavra, *Aerothermodynamics of Turbo-Machines;* Instructor's Notes. PREREQUISITES: At least two semesters combined mathematics coverage in vector analysis, partial differential equations and functions of a complex variable.

Ae 512A LAMINAR AND TURBULENT FLOW (4-0). Applications of Navier Stokes equations. Laminar boundary

layer equations. Momentum and energy integral relations for boundary layer. Exemplary solutions, exact and approximate. Transition, turbulence, turbulent stresses. Equations for turbulent flow. Mixing length theory. Turbulent boundary layers. Jets and wakes. TEXT: Schlichting, *Boundary Layer Theory*. PREREQUISITES: Ae 511A or Ae 171A.

Ae 513A COMPRESSIBLE FLOW I (4-0). One dimensional gas dynamics; channel flow with area change, friction and heat transfer. Normal and oblique shock waves. Prandtle-Meyer expansion. Linearized potential flow and application to airfoils and bodies of revolution. Similarity laws between sub-sonic and incompressible flows. Two dimensional supersonic flows by method of characteristics. TEXT: Shapiro, *The Dynamics and Thermodynamics of Compressible Fluid Flow, Vol. I*; Instructor's Notes. PREREQUISITE: Ae 511A or Ae 171A.

Ae 514A COMPRESSIBLE FLOW II (3-0). Continuation of Ae 513A. Three-dimensional supersonic flows past wings and bodies of revolution. Transonic and hypersonic flows. One-dimensional unsteady compressible flow and moving shocks. Friction and heat transfer in compressible boundary layers. Shock, boundary-layer interaction. TEXT: Shapiro,*The Dynamics and Thermodynamics of Compressible Fluid Flow, Vol. II*; Instructor's Notes. PREREQUISITE: Ae 512A, and Ae 513A or Ae 172A and Ae 173A. Also Ae 519A to be taken concurrently.

Ae 519A COMPRESSIBLE FLOW LABORATORY (0-2). Wind tunnel and shock tube tests to demonstrate aspects of the theory developed in Ae 513A and Ae 514A. TEXT: Same as in Ae 513A and Ae 514A. PREREQUISITE: Ae 514A or AE 174A, which will ordinarily be taken concurrently.

Ae 521A MAGNETOAERODYNAMICS (4-0). Dynamic equations for continuous media and classical equations for electromagnetic fields as applied to ionized gases moving in a magnetic field; propagation of small disturbances, Alfven waves, fast and slow waves, shock waves; particular solutions of the magnetoaerodynamic equations; motion of charged particles, drift, anisotropic Ohm's law, applications. TEXTS: Instructor's Notes. PREREQUISITE: Ae 514A.

Ae 531A CONDUCTIVE AND CONVECTIVE HEAT TRANSFER (4-0). Introduction, multidimensional and nonsteady conductive heat transfer, application to problems of thermal stress analysis, numerical and analogue methods of solution. Laws of similarity, boundary-layer solutions, experimental solutions, free and forced convection, compact heat exchangers and gas turbine regenerators, mass transfer, evaporation and condensation. Problems of combined convection and conduction. TEXTS: Canslaw and Jaeger, *Conduction in Solids;* Schneider, *Conduction Heat Transfer;* Jakob, *Heat Transfer, Vol. I and II;* Eckert and Drake, *Heat and Mass Transfer;* Schlicting, *Boundary Layer Theory*. PREREQUISITE: Ae 511A.

Ae 532A CONVECTIVE AND RADIATIVE HEAT TRANSFER (4-0). Continuation of convective heat transfer to include effects of compressibility and problems of high speed flight and reentry; recovery factor, non-steady flow, and blunt body stagnation point heat transfer. Transpiration, ablation, and rotating machinery. Fundamental laws of radiation, geometrical properties, the shape factor, hemispherical variation or emissivities and gas body radiation. Problems of combined convection and radiation. TEXTS: Eckert and Drake, *Heat and Mass Transfer;* Schlicting,*Boundary Layer Theory;* Jakob, *Heat Transfer, Vol. I and II*. PREREQUISITE: Ae 531A.

Ae 601A METHODS IN ELASTICITY (4-0). Formal systems in stress and strain, the generalized Hooke's Law and compatibility. Classical boundary value problems. Plane stress and strain. Airy stress function. Variational concepts; minimum potential and complementary energies. Eigenvalue solutions. Problems in elastic stability. TEXTS: Wang,*Applied Elasticity;* Sechler, *Elasticity in Engineering;* Timoshenko-Goodier, *Theory of Elasticity*. PREREQUISITE. Ae 214A.

Ae 602A STATIC AEROELASTICITY (3-0). Problems involving the coupling of aerodynamic and elastic forces without inertia coupling; the divergence of lifting surfaces and control reversal. Two-dimensional examples, related integral and differential equations, solutions for finite wings including the effect of sweep, semi-rigid solutions, iterative methods, matrix forms. TEXTS: Broadbent, *The Elementary Theory of Aeroelasticity;* Fung, *The Theory of Aeroelasticity;* Bisplinghoff, Ashley, Halfman, *Aeroelasticity*. PREREQUISITE: Ae 601A.

Ae 603A AEROELASTICITY (FLUTTER) AND VIBRATION (4-0). Problems involving coupling of inertia forces with elastic and/or aerodynamic forces. Free and forced vibrations, effect of damping, several degrees of freedom. Torsional vibration, critical speeds. Impact. Fundamental non-stationary wing theory. Flutter of a two-dimensional airfoil and of a cantilever wing. TEXTS: Same as Ae 602A. PREREQUISITE: Ae 602A.

Ae 604A THERMOELASTICITY (3-1). Analysis and design of structures at elevated temperatures. Temperature distribution, elastic and inelastic thermal stresses in aeronautical structures, thermal effects on deflections, stiffness and flutter. TEXT: Gatewood, *Thermal Stresses;* Boley, Weiner, *Theory of Thermal Stresses*. PREREQUISITE: Ae 601A.

Ae 605A PLATES AND SHELLS (4-0). Plates and shells from viewpoint of application to flight vehicles. Flat plates in bending and transverse load, curvature and twist of middle surface, bending and twisting moments, shearing forces, equilibrium equations, stresses; strain energy under lateral loading, and under loads in middle surface, plate stability; axially symmetrical shells, shell geometry, equilibrium, critical stresses; discontinuities, flanges, cutouts; selected design applications. TEXTS: Timoshenko, *Theory of Plates and Shells;* NACA and NASA Technical Notes, USNPGS Notes. PREREQUISITE: Ae 601A.

Ae 606A MATRIX STRUCTURAL ANALYSIS (4-0). Influence coefficients and energy theorems. Force (flexibility) and displacement (stiffness) methods applied to beams, frames, plates, box beams. Structural idealizations for wings, fuselages. Digital computer solutions. TEXT: McMinn, *Matrices for Structural Analysis;* Bruhn, *Analysis and Design of Flight Vehicle Structures.* PREREQUISITE: Ae 214A.

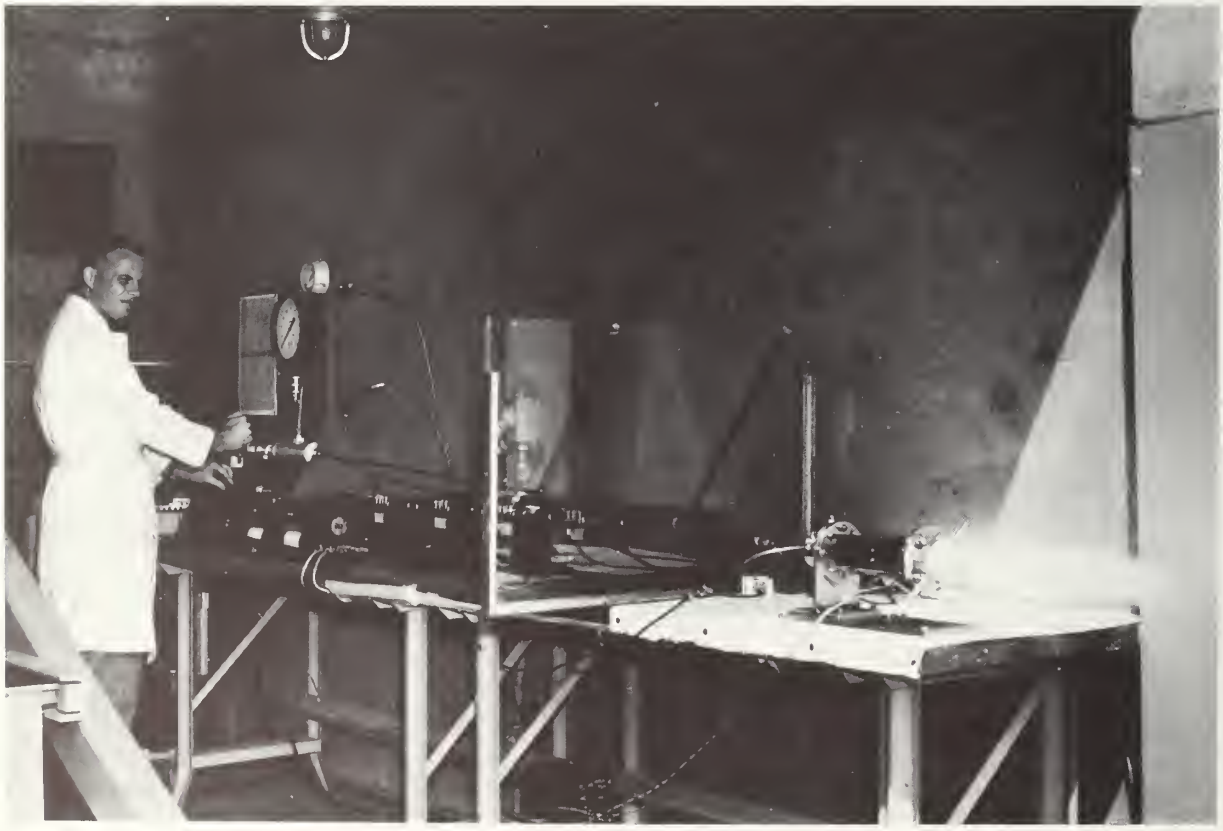
Ae 610A AERONAUTICAL STRUCTURES SEMINAR (3-0). Selected topics in advanced structural design of flight vehicles from aeroelasticity, thermoelasticity, dynamic loading and vibrations, plasticity, stability, non-linear problems, structural systems. TEXTS: Depend on topic. PREREQUISITE: Some course work in Ae 600 sequence.

Ae 623A STATIC AND DYNAMIC AEROELASTICITY (4-0). Static aeroelastic phenomena; divergence and control reversal. Finite wing examples; integrals, differential equation formulations with solutions from semi-rigid, iterative, and matrix methods. Free and forced vibration, effect of damping. Flutter mechanism; non-stationary wing theory. Applications to two- and three-dimensional lifting surfaces. TEXTS: Fung, *The Theory of Elasticity;* Bisplinghoff and Ashley, *Principles of Aeroelasticity;* Scanlon and Rosenbaum, *Aircraft Vibration and Flutter.* PREREQUISITE: Ae 601A.

Ae 633A AEROELASTICITY LABORATORY (0-3). Design and wind tunnel testing of models to demonstrate flutter, vibration, divergence and aileron reversal. TEXT: Same as Ae 623A. PREREQUISITE: Ae 623A.

Ae 701A FLIGHT SYSTEMS ENGINEERING I (3-3). Power controls and stability augmentation. Derivation of component transfer functions and block diagram concept. Basic linear servo theory. Frequency response techniques, root locus methods. Basic references for automation; single axis and multi-axis autocontrols; cross axis coupling. Performance specifications, response shaping, and application to vehicles and their sub-systems. TEXTS: Perkins and Hage, *Airplane Performance, Stability and Control;* Etkin, *Dynamics of Flight;* Raven, *Automation Control Engineering.* PREREQUISITE: Ae 107B or Ae 175A.

Ae 702A FLIGHT SYSTEM ENGINEERING II (3-2). Aeroelastic effects on stability and control, vehicle dynamics and interaction with augmentation devices and automatic controls. Automatic power control for deck recovery. Time modulated aerodynamic controls, applications to small missiles, and overall system analysis. Methods for self-adaptation of automatic controls. Analog simulation techniques. TEXTS: Same as Ae 701A. PREREQUISITE: Ae 701A.



A candidate for the Aeronautical Engineer Degree performing experiments at one of the rocket test cells.

DEPARTMENT OF BUSINESS ADMINISTRATION AND ECONOMICS

HERMAN PAUL ECKER (1957), Chairman, Professor of Management; B.A., Pomona College, 1948; M.A., Claremont Graduate School, 1949.

WILLIAM R. BAKER, Commander, SC, U.S. Navy; Instructor in Management; B.S., U.S. Naval Academy, 1946; Management, U.S. Naval Postgraduate School, 1958.

WILLIAM HOWARD CHURCH, Professor of Management (1956); B.A., Whittier College, 1933; M.S.P.A., University of Southern California, 1941.

DONALD L. CONNER, Lieutenant Commander, CEC, U.S. Navy; Instructor in Management; B.S., U.S. Naval Academy, 1955; B.C.E., Rensselaer Polytechnic Institute, 1958; M.S., U.S. Naval Postgraduate School, 1964.

JAMES BARRIE COWIE, Associate Professor of Management (1963); B.S., (honors) Glasgow University, 1938; C.I.A., Glasgow University, 1959.

JERRY LEE DAKE, Lieutenant Junior Grade, CEC, USNR; Instructor in Management; B.S., Purdue University, 1961; M.S., Purdue University, 1962.

LESLIE DARBYSHIRE, Professor of Management (1962); B.A., University of Bristol, 1950; D.B.A., University of Washington, 1957.

ROGER NILS FOLSOM, Lieutenant Junior Grade, SC, USNR; Instructor in Management; A.B., Stanford University, 1959; M.A., Claremont Graduate School, 1964.

JAMES M. FREMGEN, Associate Professor of Management (1965); B.S., University of Notre Dame, 1954; M.B.A., Indiana University, 1955; D.B.A. Indiana University, 1961; C.P.A., 1962.

FENN C. HORTON, Associate Professor of Management (1964); B.A., State University of Iowa, 1950.

H. ARTHUR HOVERLAND, Associate Professor of Management (1963); B.S., Miami University (Ohio), 1951; M.S., University of Illinois, 1954; Ph.D., University of Michigan, 1963.

JOHN M. KEENAN, Associate Professor of Management (1964); B.A., University of Colorado, 1957; M.S., University of Colorado, 1958.

SIGMUND KRAUTHAMER, Associate Professor of Management (1965); B.S., Ohio State University, 1949; Ph.D., University of Minnesota, 1963.

CLAIR ALTON PETERSON, Associate Professor of Management (1962); B.B.A., University of Minnesota, 1951; Ph.D., Massachusetts Institute of Technology, 1961.

JOHN DAVID SENGER, Associate Professor of Management (1957); B.S., University of Illinois, 1945; M.S., 1948.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN MANAGEMENT

BACHELOR OF SCIENCE

1. In addition to satisfying the Postgraduate School's general requirements for a baccalaureate degree, the degree Bachelor of Science with major in Business Administration requires a minimum of 40 term hours in general and functional Management courses at or above the C level.

2. The following requirements must be met:

Subject area	*Term Hours*
Behavioral Science	11
Quantitative Methods	11
Financial Management	11
Economics	4
Material Logistics Management	3
	40

3. The student must achieve a grade point average of at least 1.0 in subjects of the major.

MASTER OF SCIENCE IN MANAGEMENT

1. The degree of Master of Science in Management requires the completion of a minimum of 54 hours, not including the research paper, of graduate level (A and B) courses. All students are required to register for research and must present an acceptable research paper.

2. Core course requirements in A and B level courses must be successfully completed or validated by advance credit.

Discipline	*Term Hours*
Behavioral Science	13
Quantitative Methods	18
Financial Management	6
Economics	4
Material Management	3
	44

3. In addition to the core course requirements, students will choose elective sequences pertinent to their backgrounds and anticipated future assignments from the following options. A minimum of 10 hours of A or B level work beyond the core program will be required.

(1) Economics and Systems Analysis
  (a) Economics Sequence
  (b) Systems Analysis Sequence
(2) Financial Management
(3) Personnel Management
(4) Material Logistics Management

MASTER OF SCIENCE IN MANAGEMENT (DATA PROCESSING)

1. The degree Master of Science in Management (Data Processing) requires the completion of a minimum of 60 term hours, not including the thesis, of courses distributed

between the A and B level. A minimum of 24 hours must be A level. All students are required to register for research and must present an acceptable thesis.

2. Core course requirements must be successfully completed or validated by advanced credit in the following areas:

Discipline	*Term Hours*
Management	11
Mathematics	8
Data Processing	20
Operations Research	5
Statistics	12
	56

3. In addition to the core requirements, students will be expected to elect options pertinent to their future assignments. A minimum of 12 hours of A or B level work beyond the core program will be required.

MANAGEMENT

MN 010D INTRODUCTION TO ECONOMICS (4-0). A study of the operation of the American economy, its structural and institutional aspects, resources, technology, financial and monetary institutions, labor organizations and the role of government.

*MN 020D FINANCIAL MANAGEMENT (1-0). Survey of accounting principles, government budgeting, and appropriation accounting.

*MN 040D PRODUCTION MANAGEMENT (1-0). Survey of the application of management control to production processes.

*MN 053D PERSONNEL MANAGEMENT (1-0). Survey of individual and group behavior as applied to organization structures.

*MN 090D PRINCIPLES OF ORGANIZATION AND MANAGEMENT (1-0). Survey of various management principles and practices that contribute to effective achievement of managerial goals.

MN 101C INDIVIDUAL STUDY (3-0). Designed to give undergraduate students majoring in business administration opportunities to perform advanced or special studies in various aspects of management. Consent of the proposed study advisor must be secured prior to enrollment.

MN 113C INTERMEDIATE ECONOMICS (4-0). An analysis of demand, supply, the pricing of commodities, the theory of national income determination, pricing of productive services and economic dynamics.

MN 114C INTERNATIONAL ECONOMICS (4-0). Discussion of theories of international trade, tariff policy, exchange rates and trade control. Analysis of international problems and international economic organization.

MN 120C PRINCIPLES OF ACCOUNTING (4-0). A beginning course in the elements of accounting which develops the mechanics of bookkeeping through the accounting cycle and introduces the basic principles of assets and equities, income and expense, preparation of financial statements and the external and internal use of financial statements.

MN 121C MANAGERIAL ACCOUNTING (4-0). Further develops the internal use of the accounting system as a management tool. Considers financial statements analysis, introducing cost accounting as a control device and establishes the place of accounting in management decision making in industry and in government. PREREQUISITE: MN 120C.

MN 122B BUDGETING AND COMPTROLLERSHIP (4-0). Introduces budgeting as a control concept in industry: discusses application to the military departments including budget formulation, programming, budget execution. Develops the concepts of internal audit and comptrollership in industry and as applied to the Navy. PREREQUISITE: MN 121C.

MN 140C INDUSTRIAL MANAGEMENT (4-0). This course stresses the economic consequences of combining men, machines and money for production purposes. Modern tools of decision making are introduced. Construction of simple models as an aid in determining alternatives and choosing "the best" course of action is required. Subject matter includes production planning and control, facilities layout, wage incentives and measurement of labor effort. An introduction to modern production methods is presented.

MN 152C HUMAN RELATIONS (4-0). The historical background of the American worker and the growth of the modern human relations movement are examined. Such topics as individual differences among workers, communication, motivation, interpersonal relationships and the role of the manager as a leader are investigated. Emphasis is placed on the implications of human relations for the naval officer.

MN 153C PERSONNEL ADMINISTRATION (4-0). The broad area of personnel management is covered, with particular emphasis on recruitment and selection, training, promotion, performance evaluation, and the role of the labor union in both industry and the Federal Government.

MN 163C MATERIAL MANAGEMENT (4-0). This course consists of a broad overview of major and item material management and support functions as performed in the Department of Defense, the Defense Supply Agency, and the military departments, as well as an analysis of selected techniques employed in requirements determination, procurement, and inventory management of secondary items in support of the operating forces and military industrial activities.

*Offered as a special summer course to visiting officers.

MN 170C MANAGEMENT STATISTICS (4-0). Basic course in the methods and theory of statistical analysis as applied to management decision making. The course includes probability theory, data collection, sampling distributions, discrete and continuous distribution functions, testing of hypotheses, and the use of control charts.

MN 191C ORGANIZATION AND MANAGEMENT (4-0). An introduction to the principles and practices of management. The formal aspects of organizational structure, e.g., hierarchy and control and control spans are analyzed together with alternative ways of accomplishing objectives. The role of the planning and control functions is studied in addition to the tools of analysis available to managers.

MN 210C PRINCIPLES OF ECONOMICS (4-0). A study of two major economic problems; the determination of the level of national output and the allocation of resources via the price system. In the first section, the determinants of saving and investments and the roles of monetary and fiscal policy are analyzed. The remainder of the course is devoted to price determination in the product and factor markets.

MN 211C PRINCIPLES OF ECONOMICS (3-0). The determination of the level of national output and allocation of resources via the price system. Attention is focused on the determinants of saving and investment and the roles of monetary and fiscal policy.

MN 221C PRINCIPLES OF ACCOUNTING (3-0). An introduction to principles and concepts of commercial-industrial accounting; such as financial statements, accounting cycle, accounting theory, chart of accounts, accounting terminology. The course is designed to familiarize the student with management tools made available through the accounting function.

MN 252C MANAGEMENT PSYCHOLOGY (4-0). Basic psychological concepts are examined, with particular emphasis given those aspects of major importance to the manager. Current theories applicable to such topics as communication, authority, motivation, and leadership are studied and discussed. Attention is given to aiding the manager in developing sound interpersonal relationships both in the military and Civil Service organizations.

MN 253C MANAGEMENT PSYCHOLOGY (3-0). Basic psychological concepts are examined with particular emphasis given those aspects of major importance to the manager. Current theories applicable to such topics as communication, authority, motivation, and leadership are studied and discussed. Attention is given to aiding the manager in developing sound interpersonal relationships both in the military and Civil Service organizations. An abbreviated version of MN252C offered for students in the Management (Data Processing) Curriculum.

MN 270C MATHEMATICS FOR MANAGEMENT (4-0). This course is designed to provide the mathematical background needed to understand modern managerial tools and techniques. Specific areas covered include a review of algebra, probability, and a survey of calculus.

MN 381A DATA PROCESSING MANAGEMENT (4-0). This course is intended to provide a knowledge of alternative data processing systems from unit record equipment to complex computer systems. Consideration is given to the effective installation and utilization of the most suitable system for representative Data Processing tasks. The role of the manager of such a system is emphasized.

MN 382A COMPUTER APPLICATIONS (4-0). This course discusses the application of computer systems to data processing and scientific problems. This is a continuation of MN 381A.

MN 400A INDIVIDUAL RESEARCH (0-8). The student is expected to formulate a problem or select a topic considered by the faculty to be of interest and importance to management. The investigation will be undertaken independently under the supervision of one or more staff members.

MN 401A INDIVIDUAL STUDY (3-0). Designed to give the student an opportunity to continue advanced study in some aspect of management. Consent of advisor must be secured.

MN 412A MANAGERIAL ECONOMICS (4-0). General economic principles applied to managerial decision making. Practical tools which can be used to improve the allocation of the firm's resources are studied. Specific subjects include forecasting demand, cost analysis, and capital budgeting. PREREQUISITE: MN 210C.

MN 413A MICRO-ECONOMIC THEORY (4-0). This course is designed to provide more intensive study in economic analysis with principal emphasis on value and distribution theory. Analysis is made of the behavior of business firms in their pricing, production, purchasing, and employment policies, and the relationship of the individual firm to the general pricing process. PREREQUISITE: MN 210C.

MN 415A NATIONAL INCOME AND INTERNATIONAL TRADE (4-0). The first half of the course is devoted to the determinants of the level of national income—including savings, investment, and the interest rate. The second half is devoted to the basic theory of international trade and current foreign trade issues. PREREQUISITE: MN 210C.

MN 416A ADVANCED ECONOMIC ANALYSIS (4-0). A comprehensive survey of the tools of economic analysis. An investigation is made of the basis of choice by individual economic agents—the behavior of the firm, the structure of industry and the functioning of the economy. Basic concepts in model building, different types of economic models, problems and techniques of quantifying models are employed. PREREQUISITE: MN 413A.

MN 422A MANAGERIAL ACCOUNTING (3-0). Develops the managerial uses of accounting for decision making purposes in industry. Illustrates the application of commercial accounting to the Navy through the Navy Industrial Fund. Topics include job order cost accounting, standard costs variance analysis, capital budgeting decisions, budgetary control. PREREQUISITE: MN 221C.

MN 423A BUDGETING AND CONTROL (3-0). Covers the budget formulation cycle in the government with emphasis on programming decision-making techniques employed in the Department of Defense; budget execution and accounting for appropriated funds in the Navy Department. Introduces the concepts of internal audit and control and comptrollership in the Navy. PREREQUISITE: MN 422A.

MN 424A INTERNAL CONTROL AND AUDITING SEMINAR (3-0). Develops the concepts and principles of internal control and audit with emphasis on current practice in industry and current organization for audit in the Navy. Discussion of cases from industry and the Navy relating to audit practices, audit reports and utilization and the resulting problems posed to military managers. PREREQUISITE: MN 423A.

MN 425A COMPTROLLERSHIP SEMINAR (4-0). Develops the comptrollership function in industry and in the military services, including detailed analysis of placement in the organization, operating tasks, staff role and anticipated future trends. Discussion of a broad range of cases to illustrate current practice and problems. PREREQUISITES: MN 423A, MN 471A, MN 472A, MN 481A, or permission of instructor.

MN 426A COST ESTIMATING AND ANALYSIS (3-0). Develops the concepts of cost estimation, cost behavior, cost allocation, and variance analysis. Introduces the military application of cost estimation and analysis for weapons procurement decision-making and control. PREREQUISITE: MN 423A, or permission of instructor.

MN 432A SYSTEMS ANALYSIS (4-0). This course covers the application of economic concepts, probability theory, and statistics to problems of choice among various weapons systems. Approximately half of the course is devoted to the theoretical problems involved in optimum resource allocation; the remaining time is devoted to study of current weapons choice problems. PREREQUISITE: MN 413A.

MN 436A ECONOMIC ANALYSIS (4-0). Selected economic problems which pertain to efficiency in governmental decisions. Capital theory, the theory of the "second best," the applicability of general equilibrium models, relationships between economics and operations analysis, econometrics. PREREQUISITE: MN 413A.

MN 440A INDUSTRIAL MANAGEMENT (4-0). A practical, quantitative approach to organizational problems of measurement, determination of goals and decision making. The course is taught with reference to a series of problems developing the role of quantitative data and techniques in management planning and control, production, industrial economics and military logistics problems. PREREQUISITE: MN 471A, 472A.

MN 453A PERSONNEL ADMINISTRATION AND INDUSTRIAL RELATIONS (4-0). Current personnel practices in industry are examined. The background, philosophy, and regulations of Civil Service are discussed, with emphasis given industrial relations aspects of administration. Throughout the course comparisons are made between the personnel management techniques of the Federal Government and of civilian industrial organization. PREREQUISITE: MN 252C.

MN 455A PERSONNEL ADMINISTRATION SEMINAR (3-0). A combination of directed reading and individual student presentations in specialized areas is utilized. The student is given the opportunity to pursue an area of interest, prepare a paper on the selected topic, and make a presentation to the class and the instructor for their critical comment. PREREQUISITE: MN 453A.

MN 456A LABOR RELATIONS (4-0). The nature of labor problems is defined; union history and government studied; the processes of collective bargaining, the economics of the labor market, and governmental regulation of wages and unions examined. Particular emphasis is placed on employee-management relations in the Federal Service in view of the changing status of collective bargaining in this area. PREREQUISITE: MN 453A.

MN 460A MATERIAL MANAGEMENT (3-0). This course presents the functions of material planning, requirements determination, procurement, distribution, and control applied to the introduction, development, and supply support of major military programs. A broad overview is given of the various organizations of the Department of Defense in the material management field.

MN 461A PROCUREMENT AND CONTRACT ADMINISTRATION (4-0). The elements of the procurement cycle are discussed, including the requirements determination, legal, fiscal, technical, production, facilities, inspection, and termination factors involved. The various military procurement laws and regulations are reviewed and analyzed to determine their effect upon the Navy material logistics systems. PREREQUISITE: MN 460A.

MN 462A SCIENTIFIC INVENTORY MANAGEMENT (3-0). The basic concepts and formulae used to develop material demand forecasting systems and variable inventory levels are reviewed and discussed. The scientific approach to basic inventory decisions is stressed. Opportunities are provided to study and analyze several approaches which introduce mathematical inventory theory as applied to the Navy Supply System. PREREQUISITES: MN 460A, MN 471A, MN 472A.

MN 471A PROBABILITY AND STATISTICS I (4-2). An introduction to management statistics. Emphasis is placed on the application of decision theory under uncertainty in practical business and economic situations. It includes probability, expected value, utility, binomial and normal distributions, and tests of hypotheses. PREREQUISITE: MN 270C.

MN 472A PROBABILITY AND STATISTICS II (4-2). A continuation of MN 471A. It includes sampling techniques, determination of optimal sample size, tests of significance, measures of variability, confidence intervals, and regression and correlation analysis. PREREQUISITE: MN 471A.

MN 473A QUANTITATIVE DECISION MAKING (3-0). The course explores the application of science to decision making involving a survey of applicable tools of quantitative analysis. The instruction treats management decision making problems from over-all system point of view with primary emphasis on interaction of separate elements of an enterprise; examining flows of information, money, materials, manpower and capital equipment. The course stresses practical applications of mathematical and statistical tools. PREREQUISITES: MN 471A, MN 472A, MN 440A.

MN 480A FACILITIES PLANNING (3-0). The course includes analysis of the problems involved in development of requirements and programming and procurement of long lead-time support facilities. The complexity of the process brought about by technological change, modification of strategic and tactical concepts, limited budgets and the executive-legislative relationship, are examined. PREREQUISITE: MN 460A.

MN 481A COMPUTERS AND DATA PROCESSING (4-0). An introduction to digital computers, the main emphasis on the principles involved in effective implementation of computer systems. Specific programming problems from the managerial area.

MN 490A ORGANIZATION THEORY AND ADMINISTRATION (5-0). A critical appraisal of the current state of management theory with a view to developing generalizations and operational skills of value to the military manager. Inter-disciplinary contributions to the study of management are evaluated. PREREQUISITE: MN 252C.

MN 491A MANAGEMENT POLICY (4-0). An attempt is made to synthesize the various functional areas of management into a composite whole. Stress is placed on the operation of top management rather than on component parts in the processes of analysis, decision-making, action and control in achieving various goals. PREREQUISITES: MN 490A, MN 422A, MN 423A, MN 440A.

MN 492A GOVERNMENT AND BUSINESS (4-0). Public policies of national government affecting the economic, political and social order; role of government in our society; responsiveness of national government to various interest groups; defense policy, its effect upon the Navy; the budgetary process in the formulation of the National Strategy; interaction of regulatory agencies with Defense. PREREQUISITE: MN 210C.

MN 495A ORGANIZATION AND MANAGEMENT SEMINAR (3-0). A research and discussion approach to the problem areas of the theory of organization, their structure and behavior. Particular attention is given to consequences of changes in organizational environments and internal technologies. PREREQUISITE: MN 490A.

DEPARTMENT OF ELECTRICAL ENGINEERING

CHARLES HARRY ROTHAUGE, Professor of Electrical Engineering; Chairman (1949)*; B.E., John Hopkins Univ., 1940; D. Eng., 1949.

ALLEN EDGAR VIVELL, Professor of Electrical Engineering (1945); B.E., Johns Hopkins Univ., 1927; D.Eng., 1937.

ROY STANLEY GLASGOW, Dean Emeritus and Professor of Electrical Engineering (1949); B.S., Washington Univ., 1918; M.S., Harvard, 1922; E.E., Washington Univ., 1925; D.Sc., (Hon.), Washington Univ., 1961.

GEORGE ROBERT GIET, Professor Emeritus and Fellow (1925); A.B., Columbia Univ., 1921; E.E., 1923.

RICHARD CARVEL HENSEN WHEELER, Professor Emeritus (1929); B.E., John Hopkins Univ., 1923; D.Eng., Rensselaer Polytechnic Institute, 1926.

WILLIAM MALCOLM BAUER, Professor of Electronics (1946); B.S., Northwestern Univ., 1927; E.E., 1928; M.S., Harvard Univ., 1929; D.Sc. 1940.

VLADISLAV AKO BEVC, Associate Professor of Electrical Engineering (1963); B.Sc., Univ. of California, 1957; M.Sc., Univ. of California, 1958; Ph.D., Univ. of California, 1961.

JOHN MILLER BOULDRY, Associate Professor of Electrical Engineering (1946); B.S., Northwestern Univ., 1941; M.S., Brown Univ., 1956.

STEPHEN BREIDA, Associate Professor of Electronics (1958); B.S.E.E., Drexel Institute of Technology, 1952; M.S., Purdue Univ., 1954.

WILLIAM JOHN BRENNER, Assistant Professor of Electrical Engineering (1964); B.S., Merrimack College, 1962; M.S., Stanford Univ., 1964.

SHU-GAR CHAN, Associate Professor of Electrical Engineering (1964); B.S., Univ. of Washington, 1952; M.S., Columbia Univ., 1954; Ph.D., Kansas Univ., 1964.

JESSE GERALD CHANEY, Professor of Electronics (1944); A.B., Southwestern Univ., 1924; A.M., Univ. of Texas, 1930.

PAUL EUGENE COOPER, Professor of Electronics (1946); B.S., Univ. of Texas, 1937; M.S., 1939.

MITCHELL LAVETTE COTTON, Associate Professor of Electronics (1953); B.S., California Institute of Technology, 1948; M.S., Washington Univ., 1952; E.E., Univ. of California, 1954.

JAMES STEVE DEMETRY, Assistant Professor of Electrical Engineering (1960); B.S., Worcester Polytechnic Institute, 1958; M.S., USNPGS, 1960; Ph.D., 1964.

GERALD DEAN EWING, Associate Professor of Electrical Engineering (1963); A.A., College of Marin, 1955; B.S.E.E., Univ. of California, 1957; M.S.E.E., 1959; E.E., Oregon State Univ., 1962; Ph.D., 1964.

EDWARD MARKHAM GARDNER, Professor of Electrical Engineering (1948); B.S., Univ. of London, 1923; M.S., California Institute of Technology, 1938.

ALEX GERBA, JR., Associate Professor of Electrical Engineering (1959); B.E.E., Univ. of Louisville, 1947; M.S., Univ. of Illinois, 1957.

GLENN ALVIA GRAY,** Associate Professor of Electronics (1960); B.S., Univ. of California, Berkeley, 1954; M.S., 1955; Ph.D., 1958.

DAVID BOYSEN HOISINGTON, Professor of Electronics (1947); B.S., Masachusetts Institute of Technology, 1940; M.S., Univ. of Pennsylvania, 1941.

RAYMOND KENNETH HOUSTON, Professor of Electrical Engineering (1946); B.S., Worcester Polytechnic Institute, 1938; M.S., 1939.

ROY MARTIN JOHNSON, JR., Assistant Professor of Electronics (1959); B.S., Univ. of California, 1954; M.S., 1959.

CLARENCE FREDERICK KLAMM, JR., Professor of Electronics (1951); B.S., Washington Univ., 1943; M.S., 1948.

JEFFREY BRUCE KNORR, Lieutenant Junior Grade, U.S. Naval Reserve, Instructor of Electrical Engineering (1964); B.S., Pennsylvania State Univ., 1963; M.S., 1964.

GEORGE HEINEMANN MARMONT, Professor of Electronics (1959); B.S., California Institute of Technology, 1934; Ph.D., 1940.

CARL ERNEST MENNEKEN, Professor of Electronics (1942); B.S., Univ. of Florida, 1932; M.S., Univ. of Michigan, 1936.

ROBERT LEE MILLER, Professor of Electronics (1946); B.Ed., Illinois State Normal Univ., 1936; M.S., Univ. of Illinois, 1941.

RAYMOND PATRICK MURRAY, Associate Professor of Electronics (1947); B.S., Kansas State College, 1937; M.S., Brown Univ., 1953.

GLEN ALLEN MYERS, Associate Professor of Electrical Engineering (1965); B.S.E.E., Univ. of North Dakota, 1955; M.S.E.E., Stanford Univ., 1956; Ph.D., 1965.

HERBERT LEROY MYERS, Assistant Professor of Electrical Engineering (1951); B.S., Univ. of Southern California, 1951.

ROBERT SAMUEL NORIN, Lieutenant Junior Grade, U.S. Naval Reserve, Instructor of Electrical Engineering (1964); B.A., Columbia Univ., 1962; B.S., 1963; M.S., Stanford Univ., 1964.

WILLIAM EVERETT NORRIS, Associate Professor of Electronics (1951); B.S., Univ. of California, 1941; M.S., 1950.

CHARLES BENJAMIN OLER, Professor of Electrical Engineering (1946); B.S., Univ. of Pennsylvania, 1927; M.S., 1930; D.Eng., Johns Hopkins Univ., 1950.

RUDOLF PANHOLZER, Associate Professor of Electrical Engineering (1964); Dipl. Ing., Technische Hochschule Graz,

Austria, 1953; M.S.E.E., Stanford Univ., 1955; D.E., Stanford Univ., 1956; D.Sc., Technische Hochschule Graz, Austria, 1961.

ORVAL HAROLD POLK, Professor of Electrical Engineering (1946); B.S., Univ. of Colorado, 1927; M.S., Univ. of Arizona, 1933; E.E., Univ. of Colorado, 1940.

MICHAEL ALOYSIUS REILLY, Ensign, U.S. Navy, Instructor of Electrical Engineering (1964); B.S.E.E., Santa Clara Univ., 1961; M.S.E.E., 1964.

GEORGE LAWRENCE SACKMAN, Associate Professor of Electrical Engineering (1964); B.M.E., Univ. of Florida, 1954; B.E.E., 1957; M.S.E., 1959; Ph.D., Stanford Univ., 1964.

ABRAHAM SHEINGOLD, Professor of Electronics (1946); B.S., College of the City of New York, 1936; M.S., 1937.

WILLIAM CONLEY SMITH, Professor of Electrical Engineering (1946); B.S., Ohio Univ., 1935; M.S., 1939.

DONALD ALAN STENTZ, Associate Professor of Electronics (1949); B.S., Duke Univ., 1949; M.S., USNPGS, 1958.

ROBERT DENNEY STRUM, Associate Professor of Electrical Engineering (1958); B.S., Rose Polytechnic Institute, 1946.

FREDERICK WALCUTT TERMAN, Assistant Professor of Electrical Engineering (1964); B.S., Stanford Univ., 1949; M.S., 1950.

GEORGE JULIUS THALER, Professor of Electrical Engineering (1951); B.E., Johns Hopkins Univ., 1940; D.Eng., 1947.

HAROLD ARTHUR TITUS, Associate Professor of Electronics (1962); B.S., Kansas Univ., 1952; M.S., Stanford Univ., 1957; Ph.D., 1962.

JOHN BENJAMIN TURNER, JR., Associate Professor of Electronics (1955); B.S., Univ. of Arkansas, 1941; M.S., Univ. of California, 1948.

JOHN ROBERT WARD, Associate Professor of Electrical Engineering (1962); B.Sc., Univ. of Sydney, 1949; B.E., 1952; Ph.D., 1958.

MILTON LUDELL WILCOX, Associate Professor of Electrical Engineering (1958); B.S., Michigan State Univ., 1938; M.S., Univ. of Notre Dame, 1956.

*The year of joining the Postgraduate School Faculty has been indicated in parentheses.

**Absent on leave.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN ELECTRICAL ENGINEERING

In addition to meeting the minimum specific academic requirements for these degrees as given below, candidates must also satisfy the general degree requirements as determined by the Academic Council.

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

BACHELOR OF SCIENCE IN ENGINEERING ELECTRONICS

BACHELOR OF SCIENCE IN COMMUNICATIONS ENGINEERING

It is required that candidates for these degrees satisfy the following requirements while in residence at the Naval Postgraduate School except in the case of candidates entering the school with advanced standing, when due allowance will be made for advanced transfer credits.

Discipline	*Subject*	*Approximate Term Hrs.*
Electrical Engineering	Fields and Circuits	17
	Electron Devices and Circuits	16
	Electromagnetic Theory	4
	Communication Theory	4
	Electromechanical Devices	5
	Feedback Control Theory	4
	Electronic Computers	4
		54
Mathematics	Vector Algebra	4
	Calculus	4
	Differential Equations and Series	4
	Complex Variables	3
		15
Physics	Properties of Matter	8

In addition to the above 77 term hours, approximately 28 elective term hours will be required in upper division courses. At least 15 of those term hours will normally be elected in the candidate's degree option (Electrical Engineering, Engineering Electronics or Communications Engineering).

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

MASTER OF SCIENCE IN ENGINEERING ELECTRONICS

Each student's program must include a total of at least 45 term hours in A or B level courses beyond the requirements for the B.S. degree. At least 20 of these credits shall be in A level courses.

Of the above 45 credits at least 20 must be directed toward a specialty within the candidate's degree option, and in addition at least 22 non-specialty credits must be distributed as follows:

Advanced Circuits	4 term hours
Advanced Devices	4 term hours
Advanced Mathematics	6 term hours
Electives other than Electrical Engineering or Mathematics	8 term hours

In addition candidates must present an acceptable thesis.

BIOLOGY

BI 800C FUNDAMENTALS OF BIOLOGY (6-0). The fundamental principles of the living cell covered from a biochemical and biophysical standpoint. Specialization of cell function, as exemplified in certain animal and plant tissues and organs systems. Genetics and its relation to properties of cell nucleus. Related topics, including the evolutionary progress.

BI 801B ANIMAL PHYSIOLOGY (6-0). A general course in animal physiology, emphasizing human functional aspects. PREREQUISITE: BI 800C.

BI 802A RADIATION BIOLOGY (6-0). Fundamental processes of energy transfer from radiation to living matter. Biochemical, physiological and genetic effects of radiation. Methods of experimental radiation biology. PREREQUISITES: PH 637B, PH 638A, BI 800C, BI 801B.

BI 822A SPECIAL TOPICS IN RADIATION BIOLOGY (2-0). Study of important current topics in radiation biology. PREREQUISITE: Appropriate biological background.

BI 823A SPECIAL TOPICS IN RADIATION BIOLOGY II (2-0). A continuation of BI 822A. A study of important current topics in radiation hiology.

ELECTRICAL ENGINEERING

EE 101D ELECTRICAL FUNDAMENTALS (3-2). A presentation of hasic electrical phenomena. Topics include: DC circuits and components, magnetism, electromagnetism, instruments, AC circuits and components, resonance, transformers, batteries, and power sources.

EE 105C BASIC ELECTRICAL PHENOMENA (3-2). The first of a series of three courses designed to present the fundamentals of fields and circuits. An introduction to the theory of electric and magnetic fields presented in a unified manner which satisfies the prerequisites for circuits, electronics, and machinery. PREREQUISITE: Ordinary Differential Equations.

EE 106C BASIC CIRCUIT ANALYSIS I (3-2). The circuit concept is developed by the complete analysis of simple circuits. Sinusoidal steady-state solution by phasor methods is introduced. Matrix methods are used in the analysis of multi-loop and multi-node circuits. PREREQUISITE: EE 105C.

EE 107C BASIC CIRCUIT ANALYSIS II (3-2). A continuation of EE 106C. Poles and zeros are defined. Driving point, transfer, and hybrid parameters of 2-port networks; polar, logarithmic, and rectangular plots; network theorems; Fourier series; and balanced polyphase circuits are studied. PREREQUISITE: EE 106C.

EE 111C FIELDS AND CIRCUITS (4-4). An introduction to the theory of electric and magnetic fields is presented as a foundation for the study of circuits, electronics, and machinery. The basic circuit elements are defined by the application of this theory. Response of simple circuits and power and energy relations are considered. Sinusoidal steady-state solution by phasor methods is introduced. PREREQUISITE: Differential and Integral Calculus (may be concurrent).

EE 112C CIRCUIT ANALYSIS (4-3). A continuation of EE 111C. Sinusoidal analysis is continued. Poles and zeros are defined. Matrix methods are introduced. Driving point, transfer, and hybrid parameters of 2-port networks; polar, logarithmic and rectangular plots; network theorems; Fourier series; and balanced polyphase networks are studied. PREREQUISITE: EE 111C.

EE 113B LINEAR SYSTEMS ANALYSIS (4-3). The basic theory of circuit analysis is continued with a thorough study of transient phenomena in linear systems. Laplace transform methods are studied with illustrations in electrical, mechanical, and electromechanical systems. Fourier integral methods for solutions of system response and spectral analysis are considered. Real convolution and its application to inversion techniques in both Laplace and Fourier solutions is illustrated. Methods of analysis in both the time and frequency domain are compared. The analog computer is used to simulate linear systems in the laboratory. PREREQUISITES: EE 112C or EE 107C. Complex Variable Theory (may he concurrent).

EE 114B COMMUNICATION THEORY I (4-0). In this introductory course the following concepts and their mathematical formulations are presented: Information measure; sampling; pulse encoding methods; frequency and time multiplexing; amplitude, frequency and phase modulation. In addition, a comparison of modulation methods is presented. PREREQUISITE: EE 113B.

EE 116B COMMUNICATION THEORY II (3-2). A continuation of EE 114B. Noise sources and methods of measurement are treated. Statistical methods for handling noise and random signals are presented, followed by a study of detection problems in radar and pulse transmission systems. Correlation functions and their application to communication systems are introduced. PREREQUISITE: EE 114B.

EE 121A ADVANCED NETWORK ANALYSIS (3-2). Network topology, signal flow graphs, sensitivity, and general linear, scattering, and immittance descriptions are considered. Additional topics are chosen from the following partial list: Potential analog, time varying linear system analysis, response of linear systems to random signals, analytic properties of network functions. PREREQUISITE: EE 113B.

EE 122A NETWORK SYNTHESIS I (3-2). Basic principles of system synthesis as exemplified in the synthesis of passive electric networks. Energy relations in such networks and the fundamental properties of physically realizable driving point immittances are studied. Synthesis of one-port networks, in various forms, is illustrated, as is the ladder development of 2-port networks. PREREQUISITE: EE 113B.

EE 123A NETWORK SYNTHESIS II (3-0). Two-port synthesis is continued from EE 122A, with emphasis on series and parallel realizations, lattice networks, and resistively terminated networks. N-port synthesis, synthesis through matrix methods, and linear graph theory methods of synthesis are introduced. Other advanced topics in modern active and passive synthesis will be discussed. PREREQUISITE: EE 122A.

EE 131C POLYPHASE CIRCUITS (3-2). Analysis of polyphase circuits with balanced and unbalanced loading. Power and energy measurements in polyphase circuits. Analysis of polyphase circuits with unbalanced voltages using symmetrical components. Fault currents and voltages determined by the application of sequence networks. PREREQUISITE: EE 112C or EE 107C.

EE 205D ELECTRONICS FUNDAMENTALS (3-2). A qualitative approach to the fundamentals of electronics. Topics include: physical processes and operational characteristics of basic vacuum and solid-state devices; rectifiers, amplifiers, oscillators and elementary communication circuits. PREREQUISITE: EE 101D.

EE 211C ELECTRON DEVICES AND CIRCUITS I (4-2). The study of the physical processes in electron devices is introduced by a consideration of charge-carrier motion in vacuum, gases and solids. The operational characteristics of diodes, control grid vacuum tubes, and transistors are derived and basic amplifier techniques are introduced. PREREQUISITE: EE 111C or EE 106C.

EE 212C ELECTRON DEVICES AND CIRCUITS II (4-3). The topics studied include analysis of signal amplifiers, frequency response of cascaded untuned amplifier stages, and compensated, tuned, and feedback amplifiers. PREREQUISITE: EE 211C.

EE 213C PULSE AND WAVEFORMING CIRCUITS (4-3). The topics studied include sinusoidal oscillators, basic pulse techniques, relaxation oscillators, bistable and monostable switching circuits and pulse amplifiers. PREREQUISITE: EE 212C or EE 232C.

EE 214C ELECTRONIC COMMUNICATION CIRCUITS I (4-3). Power supplies, tuned and untuned power amplifiers, modulation techniques and circuits, and communication transmitters will be studied. PREREQUISITE: EE 213C.

EE 215C ELECTRONIC COMMUNICATION CIRCUITS II (4-3). Topics covered include tuned voltage amplifiers, frequency converters, detectors, automatic gain control, and noise suppressors. These circuits are then integrated into a radio receiving system. PREREQUISITE: EE 214C.

EE 216C SPECIAL ELECTRONIC DEVICES (4-2). The topics studied include particle dynamics, microwave devices, negative resistance and variable reactance devices, and a brief survey of quantum electronics and microelectronics. PREREQUISITES: EE 214C and PH 604C or equivalent.

EE 217B ADVANCED ELECTRON DEVICES (4-2). The topics studied include particle dynamics, electron beam techniques and devices, microwave devices, negative resistance and reactance devices, microelectronics and quantum-electronic devices. PREREQUISITES: EE 214C and PH 705B or equivalent.

EE 221C GENERAL ELECTRONICS I (3-3). The first of a two-term terminal course. Topics include: electronic processes in vacuum, gas and solid media; diodes and diode circuits; amplifier devices and basic amplifier techniques. PREREQUISITE: EE 112C.

EE 222C GENERAL ELECTRONICS II (3-3). A continuation of EE 221C. Included topics are: linear amplifier analysis and frequency response; large-signal, tuned and feedback amplifiers; oscillators; power supplies; communication circuits and systems. PREREQUISITE: EE 221C.

EE 223B ELECTRONIC CONTROL AND MEASUREMENT (3-3). Analysis and design of electronic circuits of control, measurement, data transmission and processing. Topics included are: vacuum-tube voltmeters, DC amplifiers, pulse-shaping and switching circuits, oscillators and time-base generators, counting and time-interval measuring circuits, frequency measurement and control circuits, motor-speed and generator-voltage control systems. PREREQUISITES: EE 232C and EE 113B (may be concurrent).

EE 231C ELECTRONICS I (4-3). The topics studied include: Charge motion in a vacuum and in solids; diodes and diode circuits; transistors and multielectrode vacuum tubes, with application to simple amplifier circuits; gaseous tubes. PREREQUISITE: EE 112C or EE 107C.

EE 232C ELECTRONICS II (4-3). Topics included are: tuned, feedback and power amplifiers; amplifier frequency response; oscillators; power supplies; large-signal amplifiers. PREREQUISITE: EE 231C.

EE 233B COMMUNICATION CIRCUITS AND SYSTEMS (4-3). The following topics are studied: amplitude and frequency modulation and detection, pulse modulation methods, frequency conversion and synthesis, transmitting and receiving systems, multiplexing techniques. PREREQUISITE: EE 232C.

EE 234C PULSE TECHNIQUES AND HIGH FREQUENCY TUBES (3-3). A study of clipping, differentiating, integrating, clamping, and coupling circuits, relaxation oscillators, and pulse amplifiers, using both tubes and transistors. Following this is a study of microwave tubes most commonly employed in radar systems. PREREQUISITE: EE 232C.

EE 253A MICROWAVE TUBES (3-2). A study of the theory and operating principles of various microwave tubes, such as traveling-wave tubes, klystrons, plasma devices, crossed-field devices. Topics to be studied will include: formation and control of electron beams, slow-wave structures, interaction between beams and waves, and coupled mode theory. PREREQUISITE: EE 622B.

EE 254B TRANSISTOR CIRCUITS (3-3). Topics: transistor parameters; amplifier performance—single and multistage feedback circuits; one- and two-stage feedback bias circuits; DC amplifiers, regulators; frequency response—high frequency, tuned and wide-band amplifiers: oscillators; power amplifiers and converters; switching applications; negative resistance devices and circuit applications. PREREQUISITE: EE 212C or EE 232C.

EE 255A QUANTUM ELECTRONICS (3-2). A review of the general laws of radiation and energy levels in atoms and solids. Principles of masers and lasers. Applications and current problems in the development of quantum electronic devices. PREREQUISITES: EE 622B and PH 705B.

EE 261B NONLINEAR MAGNETIC DEVICES (3-3). An introduction to the use of the saturable reactor as a nonlinear circuit element. Pulse, storage, counting circuits as used in data processing and digital computer technology, as well as power modulation applications are considered. Piecewise linear analysis techniques are used to develop the theory of magnetic amplifiers. The transfer function of the amplifier with and without feedback is derived. PREREQUISITES: EE 113B and EE 212C or EE 232C.

EE 271C ELECTRONIC DEVICES AND CIRCUITS I (4-2). The topics include DC and AC circuit theory, introductory principles of electronic devices and circuits, physical processes in vacuum, gaseous and semiconductor and tube devices. PREREQUISITES: Basic calculus and physics.

EE 272C ELECTRONIC DEVICES AND CIRCUITS II (4-2). The study of electronic circuits. Included topics are electronic devices as circuit elements, analysis of linear amplifiers, large-signal amplifiers and basic applications of electronic circuits. PREREQUISITE: EE 271C.

EE 281C GENERAL ELECTRONICS (4-2). A one-term survey course, for non-electrical engineering curricula, with emphasis on the general operational characteristics of representative electronic devices. Topics included are: physical processes in common devices; current-voltage relations of diodes and active devices; basic electronic circuits. PREREQUISITE: EE 112C or EE 107C.

EE 291C ELECTRONICS I (NUCLEAR) (3-3). This is the first of two courses designed to give the Nuclear Engineering student an appreciation of electronic equipment used in this science. Topics are: Steady state circuit analysis, transient concepts, and the basic theory of vacuum and semiconductor diodes, control type tubes, and transistors. PREREQUISITES: Mathematics through calculus.

EE 292C ELECTRONICS II (NUCLEAR) (3-3). This course considers vacuum tube and transistor circuits, such as power supplies, voltage amplifiers, feedback circuits, pulse amplifiers, and pulse shaping circuits. Basic concepts are then applied to a variety of special circuits, including: integral and differential discriminators; coincidence and anti-coincidence circuits, count-rate meters, and scalers. PREREQUISITE: EE 291C.

EE 301D ELECTRIC MACHINERY (3-2). The fundamentals and applications of electrical machinery. Topics include: external characteristics of shunt and compound generators; shunt, series and compound motors; alternators, induction and synchronous motors; parallel operation of alternators and generators. PREREQUISITE: EE 101D.

EE 311C ELECTRIC MACHINERY I (3-4). A study of electromagnetically coupled circuits, fixed or in relative motion. The principles common to translational and rotational electromechanical energy conversion devices are presented. These principles are applied to transformers and rotating machinery in the steady-state and dynamic modes. PREREQUISITE: EE 112C or EE 107C.

EE 312C ELECTRIC MACHINERY II (3-4). A continuation of electric machine study. Types studied are synchronous and asynchronous motors and generators, direct current motors and generators and AC and DC control machines. PREREQUISITE: EE 311C.

EE 315B MARINE ELECTRICAL DESIGN I (2-4). This is the first of two courses covering the synthesis and design of power systems and their components. The design of a transformer will be studied, in relation to both steady-state and transient performance. Protective devices and power distribution concepts will he introduced. PREREQUISITE: EE 312C.

EE 316A MARINE ELECTRICAL DESIGN II (2-4). The distribution problem will be continued with respect to unbalanced loading, fault analysis and circuit protection. The design of a motor or a generator will be studied, with consideration given to starting conditions, unbalance, motor-generator operation and stability. PREREQUISITE: EE 315B.

EE 321C ELECTROMECHANICAL DEVICES (3-4). The basic theory and operating characteristics of control machines under steady state and transient conditions. Transformers, synchros, induction motors, DC motors, DC generators, and rotary amplifiers are covered in sufficient detail to develop the concepts required in control application. PREREQUISITE: EE 112C or EE 107C.

EE 331C ELECTRICAL MACHINERY (3-3). A one term course covering the principles and applications of AC and DC machines. DC motors and generators, alternators, and both single and polyphase synchronous and induction motors are covered. Electromechanical energy conversion principles are emphasized. Dynamic and steady-state performance is treated. PREREQUISITE: EE 112C or EE 107C.

EE 411B FEEDBACK CONTROL SYSTEMS I (3-3). The mathematical theory of linear feedback control systems is considered. Topics include: writing system equations; relationship between time and frequency domain characteristics; analysis using root locus concepts and using polar and logarithmic plots; stability using Nyquist's criterion, Routh's criterion, and root locus; performance criteria and

sensitivity. Laboratory work includes simulation of control systems on the analog computer and testing and evaluation of physical systems. PREREQUISITES: EE 113B, EE 321C, and EE 212C or EE 232C.

EE 412A FEEDBACK CONTROL SYSTEMS II (3-4). Elements of design of control systems are considered, using both frequency response and s-plane methods. The fundamental methods of analysis of nonlinear control systems are presented. The phase plane and describing function methods are studied. The relay servo is introduced. PREREQUISITE: EE 411B.

EE 413A SAMPLED DATA CONTROL SYSTEMS (2-2). A study of the response of control systems to discontinuous information. The basic theory of sampling, quantizing and data reconstruction is studied. The Z-transformation and the z-plane are presented. The system transient performance and the design of compensation is presented. PREREQUISITE: EE 412A.

EE 414A STATISTICAL DESIGN OF CONTROL SYSTEMS (2-2). Statistical concepts and random signals are studied. The consideration of statistical analysis and design of linear and non-linear systems with stationary and non-stationary signal characteristics. The design of the optimum filter is studied. PREREQUISITE: EE 412A.

EE 415A LINEAR CONTROL SYSTEM SYNTHESIS (3-0). The synthesis of linear control systems is studied. Performance criteria, advanced root locus methods and Mitrovic's method are presented. The analysis and synthesis of multiloop systems are studied, using determinantal and signal flow methods. PREREQUISITE: EE 412A.

EE 416A NON-LINEAR CONTROL SYSTEMS (3-1). Phase space and state-space concepts are studied. Quasi-optimum, dual-mode and relay-control systems are presented. Optimum control methods are presented. Lyapunov's method is studied. PREREQUISITE: EE 412A.

EE 419B NON-LINEAR AND SAMPLED SYSTEMS (3-4). A terminal course in control system theory intended for students not pursuing a control option. Phase plane methods, relay control systems, and sampled-data systems are studied. PREREQUISITE: EE 411B.

EE 422B MODERN COMMUNICATIONS (3-3). A study of modern communications techniques, with emphasis on the application of theory to modern communication systems. The systems studied include frequency shift radio teletype, single-sideband and multiplex techniques. PREREQUISITE: EE 116B or EE 571A.

EE 431C INTRODUCTION TO RADAR (3-3). A one-term course designed for students not majoring in electronics. The course includes a study of search, fire-control, and radar-guidance systems with particular emphasis on pulse, FM, doppler, and mono-pulse systems. PREREQUISITES: EE 234C and EE 612C.

EE 432B THEORY OF RADAR (3-3). A one-term course designed for students majoring in electronics. The course includes a study of pulse, FM, doppler, and mono-pulse radar systems, moving target indication, data presentation, and track-while-scan systems. PREREQUISITES: EE 116B, EE 216C, and EE 612C.

EE 433A RADAR SYSTEMS (4-2). Following a brief discussion of the radar range equation, this course introduces the student to the basic concepts of pulse, CW, FM-CW, MTI, pulse-doppler, conical scan, and mono-pulse radars. Finally, some of the important aspects of radar antennas and propagation characteristics are studied. PREREQUISITES: EE 622B, Ma 321B.

EE 451A SONAR SYSTEMS ENGINEERING (4-3). A study of the theory and engineering practices of active and passive sonar systems. Emphasis is placed on the new developments in modern underwater sound systems including communications, instrumentation, and the tactical use of these systems. PREREQUISITE: Ph 432A, Secret Clearance.

EE 455B SONAR SYSTEMS (3-3). A study of sonar theory including the active and passive systems, transducers, and characteristics of the transmission medium. PREREQUISITES: Ph 450B and EE 215C, Secret Clearance.

EE 461A SYSTEMS ENGINEERING (3-2). An introduction to the engineering of large scale systems. The primary aim of this course is to increase the student's awareness of the complex interactions of various disciplines and the main recurring problems in systems engineering. Examples from large scale military weapons systems will be studied. PREREQUISITE: EE 571A.

EE 462A AUTOMATION AND SYSTEM CONTROL (3-3). A study of basic techniques and problems encountered in large computer-centered information and control systems. Typical functional requirements for tactical data systems. Analysis of data input functions, data processing functions and data utilization functions. Laboratory work is devoted to solution of problems arising from the integration of electronic computers and radar displays. Interaction between engineering design, programming and system analysis is stressed. PREREQUISITES: EE 811C, EE 433A and Ma 116B or equivalent.

EE 471B GUIDANCE AND NAVIGATION (3-0). A study of the principles underlying systems of guidance and navigation. The principal topics are: radio, radar, infra-red inertial and celestial techniques. PREREQUISITES: PH 105C, EE 215C, and EE 411B.

EE 473A MISSILE GUIDANCE SYSTEMS (3-0). Fundamentals of missile guidance systems: radio, radar, infra-red, inertial and celestial techniques. PREREQUISITES: EE 411B, EE 433A and PH 152B.

EE 481B ELECTRONIC COUNTERMEASURES (3-3). A study of radio-frequency radiation, and the characteristics of devices used for detecting and interfering with these radi-

ations. The course includes active and passive systems, spectrum analyzers, noise problems, antennas, direction-finding systems, frequency scanning and memory systems, and data processing and display. PREREQUISITES: Secret Clearance, EE 116B and EE 215C.

EE 491B NUCLEAR REACTOR INSTRUMENTATION AND CONTROL (3-3). The basic principles and methods of nuclear reactor control are presented. The treatment of the elementary reactor with temperature and poisoning feedback is given using linear feedback control system analysis. The requirements for stable operation and accuracy of automatic neutron flux control are analyzed and demonstrated, using a reactor kinetics simulator. PREREQUISITE: EE 498B or equivalent.

EE 492A NUCLEAR REACTOR POWER PLANT CONTROL (3-4). The elementary thermodynamics of the plant control loop is established and the transfer functions obtained. The dynamic performance of the basic plant is analyzed under various load conditions. Automatic plant control stability and performance using external reactor control systems are investigated. PREREQUISITE: EE 491B.

EE 498B DYNAMICS OF LINEAR SYSTEMS (3-4). This course is intended for non-EE majors. The differential equations of some typical physical systems will be derived, and Laplace transform and pole-zero concepts will be used for their solution. Both time and frequency domains will be covered. The transfer function concept will be introduced, and the discussion will be extended to feedback systems. PREREQUISITE: EE 107C or EE 112C.

EE 541A SIGNAL PROCESSING (4-0). Applications of statistical decision theory to the detection of signals in noise. Ambiguity diagrams for signals and also transducer arrays. Signal processing in detection and tracking systems. PREREQUISITES: EE 411B, EE 571A, and EE 811C.

EE 551A INFORMATION NETWORKS (3-2). Adaptations of symbolic logic for the analysis of binary information networks using relay, vacuum tubes, transistors, or magnetic cores. Abstract models for switching networks. Combinational and sequential circuits. Logical design of arithmetic and control elements. Dynamic simulation. Transfer function synthesis. Frequency domain treatment of analog and digital computer programs. PREREQUISITES: EE 113B, and EE 212C or EE 232C, and EE 812B.

EE 571A STATISTICAL COMMUNICATION THEORY (3-2). This course is a more advanced sequel to EE 114B than EE 116B. It includes a study of noise sources and a mathematical treatment of noise and random signals based on statistical methods. Transmission of such signals through linear and non-linear networks is analyzed. Statistical decision theory applications to signal detection and interpretation are illustrated by selected problems. PREREQUISITES: EE 114B and Ma 321B.

EE611C ELECTROMAGNETIC FIELDS (4-0). An introduction to electromagnetic field theory. Following a review of static electric and magnetic fields, Maxwell's equations are presented for time-varying fields. Additional topics are skin effect, plane wave propagation, and reflection of waves. PREREQUISITE: EE 112C or EE 107C.

EE 612C TRANSMISSION OF ELECTROMAGNETIC ENERGY (3-2). A study of radio-frequency transmission lines, waveguides, and related components. Classical transmission line theory is developed and applied to practical problems. The principles of rectangular and cylindrical waveguides, cavity resonators, and various microwave devices are covered. PREREQUISITES: EE 611C and EE 113B.

EE 621B ELECTROMAGNETICS I (3-2). Classical transmission line theory is developed and illustrated in laboratory exercises. The theory of static electric and magnetic fields is presented, and solutions of boundary value problems are obtained by means of scalar and vector potentials. PREREQUISITES: Ma 113B and EE 112C or EE 107C.

EE 622B ELECTROMAGNETICS II (4-0). The time-varying Maxwell equations and general boundary conditions are presented. Solutions to the wave equation in unbounded regions are studied. Maxwell's equations are applied to systems of guided waves and cavity resonators. PREREQUISITES: EE 621B and EE 113B.

EE 623A ADVANCED ELECTROMAGNETIC THEORY (3-0). Solutions to boundary value problems utilizing series solutions, transform theory, and variational techniques. PREREQUISITE: EE 622B.

EE 631B THEORY OF ANTENNAS (3-3). This course is intended to make the student familiar with the more common types of antennas and feed systems. The attack is essentially an engineering approach, applying to practical systems the mathematics and field theory presented in earlier courses. The laboratory is directed to the measurement of field intensities, antenna patterns, input impedance and feed systems. PREREQUISITE: EE 612C or EE 622B.

EE 652A MICROWAVE CIRCUITS AND MEASUREMENTS (3-2). A study of microwave components as circuit elements. Topics to be studied will include: waveguides as transmission lines, waveguide impedance concepts, matrix formulation for obstacles in waveguides, and resonant cavities as microwave circuit elements. PREREQUISITE: EE 622B.

EE 671B THEORY OF PROPAGATION (4-0). Properties of the atmosphere and its effect on the propagation of surface, space, and sky waves. Additional topics include: coverage prediction, frequency selection, noise, and tropospheric and ionospheric scatter. PREREQUISITE: EE 612C or EE 622B.

EE 711C ELECTRICAL MEASUREMENTS (2-3). An introduction to the measurement of the fundamental quantities; current, voltage, capacitance, inductance and magnetic properties of materials. Alternating current bridges,

their components and accessories; measurement of circuit components at various frequencies; theory of errors and treatment of data. PREREQUISITE: EE 112C.

EE 721A ELECTRICAL MEASUREMENT OF NON-ELECTRICAL QUANTITIES (3-3). The measurement of pressure, speed, acceleration, vibration, strain, heat, sound, light, time, displacement and other non-electrical quantities by electrical means. Consideration of special measurement problems encountered in development of missiles and missile guidance systems. PREREQUISITE: EE 212C or EE 232C.

EE 731C ELECTRONIC MEASUREMENTS (3-4). A study of the theory and techniques of electronic measurement of voltage, current, power, impedance, phase and frequency. Accuracy and precision are stressed. Measurement instruments studied include: vacuum tube voltmeters, a-f and r-f bridges, Q-meters, bolometers and power bridges, phase and frequency meters. PREREQUISITE: EE 212C.

EE 811C ELECTRONIC COMPUTERS (3-3). Basic principles of digital, analog, and incremental computers. Fundamentals of digital computer programming. Machine language, assembly language and compiler language. Elements of numerical analysis. PREREQUISITES: EE 112C or EE 107C, and Ordinary Differential Equations.

EE 812B LOGICAL DESIGN AND CIRCUITRY (4-0). Introduction to Boolean algebra. Symbolic logic and the analysis of basic logical circuits; qualitative description of basic electronic and semiconductor devices; construction of computer circuits using tubes, transistors, etc. Models for switching networks, synthesis of combinational and sequential switching circuits. Logical design of arithmetic and control elements. Memory devices, conventional and exotic. Machine-aided logical design. PREREQUISITE: EE 811C.

EE 821B COMPUTER SYSTEMS TECHNOLOGY (3-3). A course, primarily for the student not specializing in data processing, in the fundamental methods, concepts, and techniques underlying modern naval computer-oriented systems, such as NTDS and the OPCONCEN. Formulation of operational requirements. Evaluation of engineering techniques. Programming methods for large-scale command-control systems. Differing requirements of tactical versus strategic problems. The laboratory work provides the opportunity for the student to gain familiarity with methods for implementing user and command functions in a typical system environment. PREREQUISITE: EE 811C.

EE 911A INFORMATION PROCESSING SEMINAR (0-2). Discussion and reports on related topics of current interest in the field of information processing. PREREQUISITE: EE 462A or EE 551A.

EE 921A SPECIAL TOPICS IN CONTROL THEORY (0-2). An analysis of current developments in control systems, as disclosed by papers in current technical journals. PREREQUISITE: EE 412A.

EE 951E THESIS SEMINAR (0-1). In these seminar sessions, advanced students will present papers on their thesis work, which will then be discussed by other students and faculty. Some topics may be presented by faculty members.

DEPARTMENT OF GOVERNMENT AND HUMANITIES

WILLARD DWIGHT HOOT, Commander, U.S. Navy; Chairman of Department; B.A., Pennsylvania State Univ., 1939; LL.B., Univ. of Michigan, 1942; Army JAG School, Univ. of Virginia, 1956.

KENNETH LEE ABERNATHY, Lieutenant Commander, U.S. Navy; Instructor, Military Law; B.A., Washington and Lee Univ., 1955; LL.B., Yale Law School, 1958.

FRANCES E. BIADASZ, Commander, U.S. Navy; Instructor in International Relations; B.S., Worcester State Teachers College, 1935; M.A., Georgetown Univ., 1953; Ph.D., 1961.

LOFTUR L. BJARNASON, Professor of Literature (1958);* A.B., Univ. of Utah, 1934; M.A., 1936; A.M., Harvard Univ., 1939; Ph.D., Stanford Univ., 1951.

WILLIAM CLAYTON BOGGESS, Associate Professor of Speech (1956); B.S., Univ. of Southern California, 1953; M.S., 1954.

RUSSELL BRANSON BOMBERGER, Associate Professor of English (1958); B.S., Temple Univ., 1955; M.A., Univ. of Iowa, 1956; M.S., Univ. of Southern California, 1960; M.A., Univ. of Iowa, 1961; Ph.D., 1962.

BOYD FRANCIS HUFF, Professor of Government and History (1958); B.A., Univ. of Washington, 1938; M.A., Brown Univ., 1941; Ph.D., Univ. of California, 1955.

ROBERT LEONARD JACOBS, Ensign, U.S. Naval Reserve; Instructor in Political Science; A.B., North Texas State Univ., 1962; M.A., Pennsylvania State Univ., 1964.

RICHARD M. LINDENAUER, Lieutenant Junior Grade, U.S. Naval Reserve; Instructor; B.A., Stanford Univ., 1962; M.A., 1963.

RICHARD V. MONTAG, Lieutenant Commander, U.S. Naval Reserve; Assistant Professor of Political Science; A.B., College of St. Charles Borromeo, 1949; M.A., Ohio State Univ., 1952.

ARNOLD BRIAN MYERS, Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in English; B.A., Utica College of Syracuse Univ., 1961; M.A., Duke Univ., 1962.

CARL E. POHLHAMMER, Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in History; B.A., San Jose State, 1954; M.A., Univ. of California, 1957.

BURTON MACLYNN SMITH, Associate Professor of Speech (1955); B.A., Univ. of Wisconsin, 1936; M.A., 1937.

*The year of joining the Postgraduate School faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR BACHELOR OF ARTS DEGREE WITH MAJOR IN POLITICAL SCIENCE (INTERNATIONAL RELATIONS)

1. The following courses, while not part of the major proper, supply foundation and background for many of the upper-division courses that constitute the major. As soon as permitted by the schedule of the B.A. Program, candidates for the departmental major are required to complete:

Course	*Term Hours*
United States Government	4
United States History	8
Introduction to Economics	4
	16

2. The major in Political Science (International Relations) consists of a specified core of upper-division courses, plus an election of at least one upper-division course in each of three sub-disciplines or "Groups."

a. The specified core to be taken by all students pursuing the major:

Course	*Term Hours*
International Relations	4
Strategy for National Security	4
Principles of International Law	4
Development of Western Political Thought	4
International Communism	4
American Traditions and Ideals	3
European History, 1871-1919	4
European History, 1919 to present	4
Institutions and Practices of International Economics	4
	35

b. All students pursuing the major will also elect at least one course from each of the following groups:

GROUP I—AMERICAN GOVERNMENT

Course	*Term Hours*
American Diplomacy	4
American Parties and Politics	4
Institutional Processes of U.S. Government	4
American Constitutional Development	4
American Political Thought	4

GROUP II—WESTERN COMPARATIVE GOVERNMENT AND FOREIGN POLICIES

Course	*Term Hours*
Latin America	4
North Atlantic Community	4
Africa South of the Sahara	4
Government and Politics of the Soviet Bloc	4

GROUP III— EASTERN COMPARATIVE GOVERNMENT AND FOREIGN POLICIES

Course	*Term Hours*
Government and Politics of Major Asian States	4
Government and Politics of Southeast Asia	4
The Middle East	4
The Government and Politics of the Chinese Bloc	4

c. The total hours of course work in the major is 47. It can be less if required courses, specified or elective, were taken before their credits were raised from three to four hours.

3. A candidate for the degree of Bachelor of Arts with Major in Political Science (International Relations) must also satisfy the general requirements for the degree of Bachelor of Arts as determined by the Academic Council. Many of the courses required for this major are included in the B.A. curriculum. The foregoing requirements should be used by the student in planning the remainder of his B.A. program.

ENGLISH

EN 011D THESIS WRITING (2-0). A study of the principles and techniques of research writing specially designed for students in the Management Curricula.

EN 101C ADVANCED WRITING FOR NAVAL OFFICERS (3-2). Extensive practice in development of effective writing techniques and individual writing style; study of language with emphasis on its usage and application to effective writing; practice in criticism of writing examples; especially adapted to the educational needs of naval officers. PREREQUISITE: Freshman English or permission of Chairman of Department.

EN 102C REASONING AND RESEARCH REPORTING (4-0). A study of the principles of inductive and deductive logic as they are applied in the preparation of research reports.

EN 103C SEMINAR IN RESEARCH TECHNIQUES (1-0). A study of the principles and techniques of research writing.

EN 120C THE ENGLISH LANGUAGE (3-0). Lectures and exercises on the English language; its history, vocabulary, and usage.

GEOGRAPHY

GY 101C POLITICAL GEOGRAPHY (3-0). A study of world areas, regions, and countries; peoples, their distribution and political organizations.

GOVERNMENT

GV 010D U.S. GOVERNMENT (4-0). A study of the structure and powers of the Federal Government, its relation to the individual states, and its military aspects.

GV 012D AMERICAN LIFE AND INSTITUTIONS I (2-0). A study of American political institutions and political, social and economic aspects of American life. Open only to Allied officers.

GV 013D AMERICAN LIFE AND INSTITUTIONS II (2-0). A continuation of GV 012D.

GV 102C INTERNATIONAL RELATIONS (4-0). An analytical study of the basic concepts, factors and problems of international politics focused on the nature and power of the modern sovereign state and its political and economic modes of acting in its relations with other states. (Military factors in relation to foreign policy are studied in the related course GV 103C.)

GV 103C STRATEGY FOR NATIONAL SECURITY (4-0). A continuation of the analytical study of international politics with emphasis on the politico-military factors involved in the pursuit of a state's primary objective, security. These factors are studied as follows: (1) Relationship of a state's military power to its foreign policy; (2) Fundamental concepts and principles of military strategy—Clausewitz, Mahan, Douhet, Mao Tse-tung; (3) U.S. organization for national security—the Congress, the President, coordinating organizations, and the Department of Defense; (4) International organizations; (5) Disarmament.

GV 104C AMERICAN DIPLOMACY (4-0). An analysis of the major problems of the United States foreign relations in Europe, Latin America, and the Far East from 1900 to the Korean conflict.

GV 106C COMPARATIVE GOVERNMENT (4-0). An analytical and comparative study of the form and functioning of the major types of contemporary government with emphasis on the policy-making process. PREREQUISITE: GV 010D.

GV 108C THEORY AND PRINCIPLES OF INTERNATIONAL RELATIONS (4-0). A seminar in the scope and theories of International Relations and techniques of research in the field; the analysis of problems.

GV 110C GOVERNMENT AND POLITICS OF MAJOR ASIAN STATES (4-0). The international, internal, and military problems of the major Asian states, exclusive of Communist China.

GV 111C GOVERNMENT AND POLITICS OF SOUTHEAST ASIA (4-0). The international, internal, and military problems of the southeast Asian states and of Australia and New Zealand.

GV 112C LATIN AMERICA (4-0). A study of contemporary Latin America with emphasis on the problems and objectives of the constituent states, their regional and international relationships.

GV 113C THE ATLANTIC COMMUNITY (4-0). A study of the states in the Atlantic Community; their political, economic, military, ideological, and sociological relations, both regional and international.

GV 114C THE MIDDLE EAST (4-0). A study of political, economic, social, cultural and strategic aspects of the contemporary Middle East and its role in international relations.

GV 116C AFRICA SOUTH OF THE SAHARA (4-0). A study of contemporary Africa south of the Sahara with emphasis on emerging political institutions and analysis of major developing economic, social and cultural patterns.

GV 118C GOVERNMENT AND POLITICS OF THE SOVIET BLOC (4-0). An analysis of the contemporary government, economy, military doctrine, and international relations of the Soviet Union and its satellites.

GV 119C GOVERNMENT AND POLITICS OF THE CHINESE COMMUNIST BLOC (4-0). An analysis of the government, economy, institutions, military doctrine, and international relations of Communist China and its satellites.

GV 120C MILITARY LAW I (3-0). The principles of Military Law as included in the Uniform Code of Military Justice, the Manual for Courts-Martial and the Manual of the Judge Advocate General. Topics include: jurisdiction; charges and specifications; substantive law; and the law of evidence.

GV 121C MILITARY LAW II (3-0). Procedural aspects of Military Law and relations with civil authorities in legal matters. Topics include: non-judicial punishment; courts of inquiry; investigations; summary and special courts-martial; trial techniques; civil and criminal process. PREREQUISITE: GV 120C.

GV 122C INTERNATIONAL LAW (4-0). A survey of the basic principles of international law with emphasis on jurisdiction and the rules of warfare. Case and problem discussions.

GV 130C AMERICAN PARTY POLITICS (3-2). The nature and function of political parties; origin, development, structure, internal management and control; relation of parties and pressure groups to legislation and administration; analysis of voting behavior and participation in politics. PREREQUISITE: GV 010D.

GV 131C POLICY-MAKING PROCESSES OF U.S. GOVERNMENT (3-2). A seminar in the structure and functioning of American political institutions with particular emphasis upon the forces which shape and condition the decision-making processes in Congress, the Executive branch and the Judicial system. PREREQUISITE: GV 010D.

GV 132C AMERICAN CONSTITUTIONAL DEVELOPMENT (4-0). An examination of the United States Constitution and its development through the years as interpreted by Supreme Court decisions and by Congressional and Presidential traditions and practices. Constitutional issues such as federalism, civil-military relations, public v. private interests, and civil rights will be discussed. PREREQUISITE: GV 010D.

GV 140C DEVELOPMENT OF WESTERN POLITICAL THOUGHT (4-0). An historical and analytical study of major Western political thought from Plato to Rousseau with emphasis on the antecedents of modern democratic and totalitarian philosophies. Readings from original sources.

GV 141C AMERICAN TRADITIONS AND IDEALS (3-0). The traditions, ideals and values of our civilization and the role of the military in implementing the image of America in the world. PREREQUISITES: HI 101C or HI 102C, GV 140C.

GV 142C INTERNATIONAL COMMUNISM (4-0). A study of communism: the development of its theory, strategy and tactics; their application to the conquest and consolidation of power; success and failures; comparison with other totalitarian systems; contrast with principles and processes of democracy.

GV 143C THE DEVELOPMENT OF AMERICAN POLITICAL THOUGHT (4-0). A study of American political thought from the colonial period to the present. PREREQUISITES: GV 140C, HI 101C, HI 102C.

GV 150C GREAT ISSUES (3-0). Seminar on the issues confronting the United States correlating the knowledge gained in previous courses in order to develop responses to the challenges facing the United States. PREREQUISITE: Permission of Chairman of Department.

GV 199C DIRECTED STUDIES (2-0 to 4-0). Independent study in government in subjects in which formal course work is not offered. PREREQUISITE: Permission of Chairman of Department.

HISTORY

HI 101C U.S. HISTORY (1763-1865) (4-0). The development of the Federal Union from the American Revolution to the end of the Civil War.

HI 102C U.S. HISTORY (1865-present) (4-0). The development of the American nation from the reconstruction crisis to the present.

HI 103C EUROPEAN HISTORY (1871-1919) (4-0). The international, internal and military development of the major European states in the period before World War I.

HI 104C EUROPEAN HISTORY (1919-present) (4-0). The international, internal, and military development of the major European states since World War I.

HI 105C THE AGE OF REVOLUTION AND REACTION IN EUROPE (4-0). The impact of revolution on European power relationships, 1789 to 1870.

HI 199C DIRECTED STUDIES (2-0 to 4-0). Independent study in history in subjects in which formal course work is not offered. PREREQUISITE: Permission of Chairman of Department.

LITERATURE

LT 010D APPRECIATION OF LITERATURE (3-0). An introduction to the understanding and enjoyment of literature expressing the enduring problems of mankind. Style and structure will be considered as well as content. Some attention will be paid to genres and periods of literature.

LT 101C MASTERPIECES OF AMERICAN LITERATURE (3-0). A study of those ideas which have shaped American cultural life and reflect American thinking.

LT 102C MASTERPIECES OF BRITISH LITERATURE (3-0). A study of the significant ideas of selected British thinkers as they pertain to social and cultural life.

LT 103C MASTERPIECES OF BRITISH LITERATURE (continued) (3-0).

LT 104C, LT 105C MASTERPIECES OF EUROPEAN LITERATURE (3-0, 3-0). A study of the significant ideas of European writers. Plays, novels, short stories, essays, and criticisms will be read and discussed. 104 covers the period from early times to the end of the Renaissance. 105 covers the period from the Renaissance to the present time.

LT 106C, LT 107C, LT 108C MASTERPIECES OF RUSSIAN LITERATURE (3-0, 2-0, 2-0). A study of selected Russian and Soviet writers to demonstrate the role of literature in Russian and Soviet life and culture. 106, a survey of Russian literature from the early period through the 19th century, exclusive of the novel (3-0). 107, a study of the Russian novel of the 19th century (2-0). 108, a study of Soviet literature (2-0).

LT 109C PHILOSOPHICAL TRENDS IN MODERN LITERATURE (3-0). An examination of modern literature expressing social, psychological, and cultural problems in order to show how literature reflects the aspirations and the frustrations of modern man. PREREQUISITE: Permission of Chairman of Department.

LT 110C THE LITERATURE OF NORTHERN EUROPE (2-0). A study of selected writers of Germany, Scandinavia, and the British Isles, with particular reference to the dramatists such as Hauptmann, Ibsen, Strindberg, and Shaw to demonstrate their influence on the social and philosophical thinking of their times.

LT 111C THE AMERICAN NOVEL (2-0). A study of the novel in the United States from Charles Brockden Brown to William Faulkner.

LT 112C THE BRITISH NOVEL (3-0). A study of selected British novels together with consideration of their effects on the political, social and cultural life of the time.

LT 115C SHAKESPEARE (3-0). A study of selected Shakespearean sonnets and dramas.

PSYCHOLOGY

PY 010D INTRODUCTION TO PSYCHOLOGY (4-0). A survey of principles underlying human behavior with emphasis on the application of these principles to human relations and problems of social adjustment.

PY 101C APPLIED PSYCHOLOGY (3-0). A study of group dynamics, rating procedures, criminology, and personality formation and adjustment; individual projects are assigned. PREREQUISITE: PY 010D.

SPEECH

SP 001D BASIC SPEECH FOR FOREIGN OFFICERS (2-0). Intensive work in preparation and presentation of public speeches. Emphasis on special problems in public speaking for students with limited experience in English. (SP 001 is a prerequisite for SP 010 for foreign officers.)

SP 010D PUBLIC SPEAKING (3-0). Intensive work in preparation and presentation of public speeches. Emphasis on study of methods of platform techniques and principles of oral style.

SP 011D CONFERENCE PROCEDURES (3-0). Theory and practice in group dynamics applied to conferences, emphasizing completed staff work in group problem solving.

SP 012D ART OF PRESENTATION (2-0). A brief summer course in speech for first year students, with emphasis on organization and delivery.

SP 101C ADVANCED SPEECH (2-0). A study through practice of techniques in obtaining desired audience response. PREREQUISITE: SP 010D.

DEPARTMENT OF MATERIAL SCIENCE AND CHEMISTRY

GILBERT FORD KINNEY, Professor of Chemical Engineering; Chairman (1942)*; A.B., Arkansas College, 1928; M.S., Univ. of Tennessee, 1930; Ph.D., New York Univ., 1935.

NEWTON WEBER BUERGER, Professor of Metallurgy (1942); B.S., Massachusetts Institute of Technology, 1933; M.S., 1934; Ph.D., 1939.

PETER MCLAUCHLIN BURKE, Assistant Professor of Metallurgy (1960); B.S., Stanford Univ., 1956; M.S., 1957.

JOHN ROBERT CLARK, Professor of Metallurgy (1947); B.S., Union College, 1935; Sc.D., Massachusetts Institute of Technology, 1942.

THOMAS DAVID COUGHLEN, Lieutenant, USN (1964); B.S. in Ch.E., Univ. of New Mexico, 1960; M.S., in Ch.E., Univ. of California, 1965.

JOHN HENRY DUFFIN, Associate Professor of Chemical Engineering (1962); B.S., Lehigh Univ, 1940; Ph.D., Univ. of California, 1959.

WILLIAM WISNER HAWES, Professor of Metallurgy and Chemistry (1952); B.S., Ch.E., Purdue Univ., 1924; Sc.M., Brown Univ., 1927; Ph.D., 1930.

CARL ADOLF HERING, Professor of Chemical Engineering (1946); B.S., Oregon State College, 1941; M.S., Cornell Univ., 1944.

GEORGE DANIEL MARSHALL, JR., Professor of Metallurgy (1946); B.S., Yale Univ., 1930; M.S., 1932.

GEORGE HAROLD MCFARLIN, Professor of Chemistry (1948); B.A., Indiana Univ., 1925; M.A., 1926.

ROBERT HUDSON RANDALL, Lieutenant Junior Grade, U.S. Naval Reserve (1963); B.A., Los Angeles State College, 1960; M.S. in Material Science, USNPGS, 1965.

RICHARD ALAN REINHARDT, Associate Professor of Chemistry (1954); B.S., Univ. of California, 1943; Ph.D., 1947.

MELVIN FERGUSON REYNOLDS, Professor of Chemistry (1946); B.S., Franklin and Marshall College, 1932; M.S., New York Univ., 1935; Ph.D., 1937.

CHARLES FREDERICK ROWELL, Assistant Professor of Chemistry (1962); B.S., Syracuse Univ., 1956; M.S., Iowa State Univ., 1959; Ph.D., Oregon State Univ., 1964.

JOHN WILFRED SCHULTZ, Associate Professor of Chemistry (1958); B.S., Oregon State College, 1953; Ph.D., Brown Univ., 1957.

JAMES EDWARD SINCLAIR, Associate Professor of Chemistry (1946); B.S., Ch.Eng., Johns Hopkins Univ., 1945; M.S., USNPGS, 1956.

GLENN HOWARD SPENCER, Associate Professor of Chemistry (1962); B.S., Univ. of California, 1953; Ph.D., Univ. of Washington, 1958.

WILLIAM MARSHALL TOLLES, Assistant Professor of Chemistry (1962); B.A., Univ. of Connecticut, 1958; Ph.D., Univ. of California, 1962.

JAMES WOODROW WILSON, Professor of Chemical Engineering (1949); B.A., Stephen F. Austin State, 1935; B.S. in Ch.E., Univ. of Texas, 1939; M.S. in Ch.E., Texas A.&M. College, 1941.

*The year of joining the Postgraduate School faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN CHEMISTRY

BACHELOR OF SCIENCE IN CHEMISTRY

1. A specific curriculum should be consistent with the general minimum requirements for a Bachelor of Science degree as determined by the Academic Council.

2. A major in chemistry should include a minimum of 54 term hours in chemistry (of which 11 term hours are elective), 21 term hours of physics (through general and modern physics), 18 term hours of mathematics (through calculus), and 15 term hours of elective upper division courses in engineering, mathematics, or science (including chemistry). At least 108 of the term hours must be of upper division level.

3. The following specific requirements must be meet. Courses marked with an asterisk must include laboratory work.

Discipline	*Subject*	*Approximate Term Hours*
Chemistry	General*	8
	Inorganic*	5
	Analytical*	4
	Organic*	12
	Physical*	14
		43
Physics	General*	16
	Modern (Atomic)	5
		21
Mathematics	College Algebra and Trigonometry	5
	Analytical Geometry and Calculus	13
		18

4. The 11 elective term hours in chemistry must be fulfilled by taking at least upper division courses in chemistry or chemical engineering.

5. In addition to the general requirement of an overall 1.0 grade point average, an overall chemistry grade point average of 1.0 is required.

MASTER OF SCIENCE IN CHEMISTRY

1. To obtain the degree, Master of Science in Chemistry, the student must have completed work equivalent to the following: Two terms of General Chemistry, one term of Intermediate Inorganic Chemistry or Inorganic Qualitative Analysis, one term of Quantitative or Instrumental Analysis, one term of Thermodynamics, two terms of Physical Chemistry, three terms of Organic Chemistry, one term of Elementary Differential Equations and four terms of Physics.

2. In addition the student must successfully complete the following:

a. One course at the A level in each of the following areas: Chemical Thermodynamics, Inorganic Chemistry, Physical-Organic Chemistry, and Quantum Chemistry. Minimum Total term hours—12.

b. Two or more courses at the A level in the general area chosen for specialization. These courses must have a total of not less than six term hours of lecture and must be approved by the Department of Metallurgy and Chemistry. Minimum Total term hours—6.

c. A thesis demonstrating ability to perform independent and original work.

d. Sufficient supporting courses in science, mathematics and engineering to meet school requirements.

MASTER OF SCIENCE IN MATERIAL SCIENCE

1. The following is a statement of departmental minimum requirements for the degree of Master of Science in Material Science. It is noted that the candidates for this degree must also satisfy the general degree requirements determined by the Academic Council. A candidate shall previously have satisfied the requirements for a Bachelor's degree with a major in science or engineering. Credit requirements in succeeding paragraphs must be met by courses in addition to those used to satisfy this requirement.

2. A minimum credit of 20 term hours in A level courses in Material Science is required. These shall include at least one course each in the areas of metals, of ceramics, and of plasties. A minimum of 12 term hours of graduate credit must be earned outside the major department. A total of at least 24 term hours of A level courses must be included in the program.

3. Completion of a thesis and its acceptance by the department are required. A maximum of eight term hours of graduate credit may be allowed towards satisfaction of the School requirement for 48 term hours, but the thesis credit may not be used to satisfy the requirements of paragraph 2.

4. Any program leading to award of this degree must be approved by the Department of Material Science and Chemistry at least three terms before completion. In general, approved programs will require more than minimum degree requirements in order to conform to the needs and objectives of the United States Navy.

CHEMICAL ENGINEERING

EC 105C AEROMATERIALS (3-2). Review of selected principles in inorganic, organic and physical chemistry and their application to problems in aero materials. TEXT: Popovich and Hering, *Fuels and Lubricants.* PREREQUISITE: None.

EC 112A FUELS, COMBUSTION, HIGH TEMPERATURE THERMODYNAMICS (3-2). A brief survey of the organic and physical chemistry necessary for a study of the problems associated with fuels. The nature of conventional fuels and of high-energy fuels, their limitations, and possible future development. Also methods of reaction rate control. TEXTS: Popovich and Hering,*Fuels and Lubricants,* and Penner, *Chemical Problems in Jet Propulsion.* PREREQUISITES: Physical Chemistry and Thermodynamics.

EC 122D FUEL AND OIL CHEMISTRY (4-2). A study of fuels and luhricants from an engineering aspect. Topics discussed include combustion and lubrication theory, properties of fuels and lubricants and occurrence and refining of petroleum. TEXT: Popovich and Hering, *Fuels and Lubricants.*

EC 521A PLASTICS AND HIGH POLYMERS (3-2). A study of the general nature of plastics and high polymers, their application and limitations as engineering materials. Also, correlation between properties and chemical structure. In the laboratory plastics are made, molded, tested and identified. TEXT: Kinney, *Engineering Properties and Applications of Plastics.* PREREQUISITE: Ch 103D or Ch 107D.

EC 542B REACTION MOTORS (3-2). A study of the fundamentals of Rocket Motors. The subject matter includes the basic mechanics of Jet Propulsion engines, properties of solid and liquid propellants, the design and performance parameters of rocket motors. In the laboratory periods representative problems are solved. TEXT: Sutton, *Propulsion Elements.* PREREQUISITE: EC 611C or consent of instructor.

EC 571B EXPLOSIVES CHEMISTRY (3-2). Chemical and physical properties of explosives are related to modes of behavior and physical principles of use. Basic principles of testing and evaluation of explosives. Trends in new developments are surveyed. Independent exploratory work in the laboratory in such areas as manner of initiation, sensitivity, brisance, power, heats of explosion and combustion. TEXT: Cook, *Science of High Explosives.* PREREQUISITES: Thermodynamics and Physical Chemistry.

EC 591B BLAST AND SHOCK EFFECTS (3-0). Generation of blast and shock waves by explosions, propagation of shock waves in air, scaling laws for explosions, shock and blast loads on structures, damage and damage

mechanisms, thermal and ionizing radiation effects, principles of protection against damage. TEXT: Kinney, *Shocks in Air.* PREREQUISITES: Physical Chemistry and Thermodynamics.

EC 611C GENERAL THERMODYNAMICS (3-2). A treatment of the laws of classical thermodynamics with emphasis on the analysis of processes by use of the thermodynamic state functions. Applications are made to simple systems, but principles developed provide a foundation for specialized material. TEXTS: Zemansky, *Heat and Thermodynamics, 4th Ed.;* Kiefer, Kinney and Stuart, *The Principles of Engineering Thermodynamics.* PREREQUISITES: Ch 107D or Ch 103D.

EC 711B CHEMICAL ENGINEERING CALCULATIONS (3-2). Engineering problems involving mass and energy relations in chemical and physical-chemical processes. TEXT: Hougen, Etc., *Chemical Process Principles, Part I.* PREREQUISITE: Ch 103D or Ch 107D.

EC 721B UNIT OPERATIONS I (3-2). An introduction to the study of the unit operations of chemical engineering. Selection of and primary emphasis on particular unit operations will be made on the basis of current student specialties. TEXT: Smith and McCabe, *Unit Operations of Chemical Engineering.* PREREQUISITE: Physical Chemistry.

EC 722B UNIT OPERATIONS II (3-2). A continuation of EC 721B with emphasis on mass transfer operation. TEXT: Smith and McCabe, *Unit Operations of Chemical Engineering.* PREREQUISITE: EC 721B.

EC 741A HEAT TRANSFER (3-2). The fundamentals of heat transfer by conduction, convection and radiation and their application to problems in ordnance. In the laboratory periods problems illustrating these principles are solved. TEXTS: Schenck, *Heat Transfer Engineering;* McAdams, *Heat Transmission.* PREREQUISITE: Consent of instructor.

EC 750A APPLIED MATHEMATICS IN CHEMICAL ENGINEERING (3-2). The differential equations describing various chemical engineering processes are derived and solved using analytic and numeric techniques. Electronic computers will be used to obtain solutions to problems. TEXT: Sherwood, Mickley and Reed, *Applied Mathematics in Chemical Engineering.* PREREQUISITE: EC 721B.

EC 760A CHEMICAL ENGINEERING KINETICS (3-2). Rate equations are postulated for various chemical reactions and the application of these equations studied using electronic computers. Chemical reactors will be designed using rate equations obtained. Design variations will be studied by using computers. TEXT: Smith, *Chemical Engineering Kinetics.* PREREQUISITE: EC 721B.

EC 770A PROCESS CONTROL (3-2). Differential equations are set up to describe the behavior of processes occurring in chemical and physical plants. Response of these equations to various forcings are determined. Feed-back control elements are incorporated in the processes and system response determined. Stability and frequency behavior are investigated. Use is made of digital and analog computers to simulate processes and their feed-back control. TEXT: Shilling, *Process Dynamics and Control.* PREREQUISITE: Physical Chemistry and Thermodynamics.

EC 771A PROCESS CONTROL (3-2). A continuation of EC 770 wherein complex control systems are studied. These include valves and transmission lines, heat exchangers, level control, flow control, control of distillation columns and chemical reactors and finally blending and pH control. Sampled data systems and optimization techniques are considered. TEXT: Harriott, *Process Control.* PREREQUISITE: EC 770A.

CHEMISTRY

CH 001D INTRODUCTORY GENERAL CHEMISTRY I (4-3). The first term of a two-term course in elementary chemistry for students who have not had college chemistry. A study of the principles which govern the physical and chemical behavior of matter with sufficient descriptive chemistry to illustrate these principles. Laboratory experiments will be related to the lecture material. TEXTS: Sienko and Plane, *Chemistry;* Ritter, *An Introductory Laboratory Course in Chemistry.*

CH 002D INTRODUCTORY GENERAL CHEMISTRY II (3-3). The second term of the sequence described under CH 001D. Particular emphasis on the properties of compounds as related to the periodic table is used to organize the study. PREREQUISITE: CH 001D.

CH 103D GENERAL CHEMISTRY (4-2). A survey of the principles governing the chemical behavior of matter. Descriptive chemistry is limited almost entirely to the compounds of carbon on the assumption that students will have had college chemistry. TEXT: Pauling, *General Chemistry.* PREREQUISITE: College Chemistry.

CH 106D PRINCIPLES OF CHEMISTRY I (3-2). The first course of a two-term sequence. A study of the fundamental principles of chemistry governing the physical and chemical behavior of matter. Current theories of atomic structure and chemical bonding are particularly emphasized. Also studied are the states of matter, chemical kinetics, and chemical equilibria. Elementary physical chemistry experiments are performed in the laboratory. TEXT: Sienko and Plane, *Chemistry.* PREREQUISITE: College Chemistry.

CH 107D PRINCIPLES OF CHEMISTRY II (3-2). A continuation of CH 106D. The principles of chemistry are applied to the study of the chemical properties of the elements and their compounds. Special attention is given to the compounds of carbon. Laboratory experiments are used to illustrate the chemical behavior of matter. TEXT: Sienko and Plane, *Chemistry.* PREREQUISITE: CH 106D.

CH 108C INORGANIC CHEMISTRY (3-4). An intensive treatment at an intermediate level of the chemistry of the common ions in aqueous solution. The course will supplement general chemistry and will emphasize facility in the use of equilibria, kinetics, and structure in correlating the chemistry of the more familiar elements. TEXTS: Clifford, *Inorganic Chemistry of Qualitative Analysis;* King, *Qualitative Analysis and Electrolytic Solutions.* PREREQUISITE: CH 107D.

CH 109D GENERAL AND ORGANIC CHEMISTRY (3-2). This course provides a continuation of the chemical principles begun in CH 106D and also provides the minimal coverage of organic chemistry for students who will take courses in biology. TEXTS: Sienko and Plane, *Chemistry;* Hart and Schuetz, *A Short Course in Organic Chemistry.* PREREQUISITE: CH 106D.

CH 150A INORGANIC CHEMISTRY, ADVANCED (4-3). Applications of thermodynamics, chemical kinetics, and reaction mechanisms to inorganic systems. Structures of inorganic species. Aqueous solution chemistry of selected elements. A systematic approach to the chemistry of the halogens is studied in the laboratory. TEXT: Gould, *Inorganic Reactions and Structure.* PREREQUISITES: CH 108C; CH 231C; CH 444B (may be taken concurrently).

CH 231C QUANTITATIVE ANALYSIS (2-4). A study of the principles and calculations of quantitative analysis, accompanied by typical volumetric and gravimetric determinations in the laboratory. TEXT: Pierce and Haenisch, *Quantitative Analysis.* PREREQUISITE: CH 107D.

CH 302C SURVEY OF ORGANIC CHEMISTRY (4-2). A brief introduction to organic substances and their reactions, accompanied by the preparation of some representative examples. TEXT: Hart and Schuetz, *A Short Course in Organic Chemistry.* PREREQUISITE: CH 107D.

CH 311C ORGANIC CHEMISTRY I (3-2). The first term of a three-term study of the chemistry of organic compounds with appropriate laboratory supplementation. TEXT: Cram and Hammond, *Organic Chemistry.* PREREQUISITE: CH 107D.

CH 312C ORGANIC CHEMISTRY II (3-2). A continuation of CH 311C. The study of organic chemistry is pursued further with the emphasis in the laboratory on synthetic techniques. TEXT: Cram and Hammond, *Organic Chemistry.* PREREQUISITE: CH 311C.

CH 313B ORGANIC CHEMISTRY III (3-2). The final term in a three-term sequence. The discussion of organic chemistry is extended to the areas of current advances in both organic and biochemistry as applications of the material in the two earlier terms. PREREQUISITE: CH 312C or the permission of the instructor.

CH 320A ADVANCED ORGANIC CHEMISTRY I (3-2). First of a two-term sequence in which modern synthetic techniques are discussed and the application of kinetic and steric control considered. PREREQUISITE: CH 313B.

CH 321A ADVANCED ORGANIC CHEMISTRY II (3-2). Continuation of CH 320A. PREREQUISITE: CH 320A.

CH 323A THE CHEMISTRY OF HIGH POLYMERS (3-0). A treatment of the principal classes of natural and synthetic high polymers, including preparation, structure, and properties. TEXT: Golding, *Polymers and Resins.* PREREQUISITE: CH 313B.

CH 324A QUALITATIVE ORGANIC CHEMISTRY (2-4). Identification of organic compounds on the basis of physical properties, solubility, classification reactions, and the preparation of derivatives. TEXT: Shriner, Fuson and Curtin, *Identification of Organic Compounds.* PREREQUISITE: CH 313B.

CH 325A QUANTITATIVE ORGANIC ANALYSIS (1-4). The quantitative estimation of organic compounds based on the use of reactions of the functional groups. TEXT: Fritz and Hammond, *Quantitative Organic Chemistry.* PREREQUISITE: CH 313B.

CH 327A NATURAL PRODUCTS (4-0). A limited introduction to the chemistry of steroids, terpenes, and alkaloids, with emphasis on the role of stereochemistry in the physiological and chemical properties of these systems. TEXT: Fieser and Fieser, *Steroids.* PREREQUISITE: CH 313B.

CH 328A PHYSICAL ORGANIC CHEMISTRY I (4-0). First term of a two-term sequence. In this term the tools available for the study of organic mechanisms are discussed and appropriate examples used. PREREQUISITE: CH 313B.

CH 329A PHYSICAL ORGANIC CHEMISTRY II (3-0). The techniques discussed in CH 328A are used in the study of organic reaction mechanisms as currently understood. PREREQUISITE: CH 328A.

CH 405B PHYSICAL CHEMISTRY (4-2). Not open to students who have had a course in thermodynamics at the USNPGS. A survey course, including such topics as properties of matter, thermochemistry, chemical equilibria, kinetics. TEXTS: Daniels and Alberty, *Physical Chemistry;* Daniels, et al., *Experimental Physical Chemistry.* PREREQUISITE: CH 107D or CH 103D.

CH 407B PHYSICAL CHEMISTRY (3-2). A one-term course in physical chemistry for students who have had thermodynamics. Gases, liquids, solids, solutions, thermochemistry, chemical equilibria and kinetics are studied. TEXTS: Daniels and Alberty, *Physical Chemistry;* Daniels, et al., *Experimental Physical Chemistry.* PREREQUISITES: CH 107D or CH 103D; and one term of thermodynamics.

CH 443B PHYSICAL CHEMISTRY I (4-3). The first term of a two-term sequence in physical chemistry. The sequence will include such topics as properties of matter,

thermochemistry, chemical thermodynamics, chemical equilibria, kinetics, and electrochemistry. TEXTS: Daniels and Alberty, *Physical Chemistry;* Daniels, et al., *Experimental Physical Chemistry.* PREREQUISITES: CH 107D, EC 611.

CH 444B PHYSICAL CHEMISTRY II (3-3). The second term of the sequence begun by CH 443B. PREREQUISITE: CH 443B.

CH 454B INSTRUMENTAL METHODS OF ANALYSIS (3-3). A course designed to familiarize the student with modern instrumental techniques of chemical analysis. Emphasis is given to the theoretical basis of the various kinds of measurements made in the laboratory and the principles involved in the design and construction of analytical instruments. Laboratory experiments will deal with representative analytical problems. TEXT: Willard, Merritt and Dean, *Instrumental Methods of Analysis.* PREREQUISITE: CH 444B.

CH 464A ELECTROCHEMISTRY (3-0). A detailed treatment of modern electrochemistry and the structure of solutions. TEXT: Robinson and Stokes, *Electrolyte Solutions.* PREREQUISITE: CH 444B.

CH 466A CHEMICAL KINETICS (3-0). Experimental methods and interpretation of data. Mechanisms of reactions. Collision theory and activated-complex theory. TEXT: Frost and Pearson, *Kinetics and Mechanism.* PREREQUISITE: CH 444B.

CH 467A QUANTUM CHEMISTRY I (3-0). A study of the fundamental principles governing the quantum behavior of matter. Topics will include the Heisenberg uncertainty principle, the Pauli exclusion principle, and the use of quantum mechanics in describing the electronic structures of atoms and simple molecular systems. TEXT: Pauling and Wilson, *Introduction to Quantum Mechanics.* PREREQUISITE: CH 444B.

CH 468A QUANTUM CHEMISTRY II (3-0). The application of quantum mechanics to polyatomic molecules. Use will be made of valence-bond and molecular-orhital methods along with group theory in constructing approximate wave functions for describing typical molecular systems. The discussion will extend to current journal articles. PREREQUISITE: CH 467A.

CH 469A QUANTUM CHEMISTRY III (3-0). The application of quantum chemistry to prediction of molecular structure; theoretical and experimental methods. Modern uses of ultraviolet, visible, infrared, microwave, electron paramagnetic resonance, and nuclear magnetic resonance spectra. PREREQUISITE: CH 468A.

CH 470A CHEMICAL THERMODYNAMICS (3-0). Application of thermodynamics to real gases, non-electrolytes, electrolytic solutions, multicomponent solutions. Calculations of equilibria, estimation of thermodynamic quantities and brief discussion of calculations of thermodynamic properties from spectroscopic and other molecular data. TEXT: Lewis and Randall, *Thermodynamics, 2nd Ed.* PREREQUISITES: EC 611C and CH 444B.

CH 540A NUCLEAR CHEMISTRY I (3-0). An introduction to the reactions of nuclei. Behavior and properties of unstable species. TEXT: Friedlander and Kennedy, *Nuclear and Radiochemistry.* PREREQUISITE: CH 150A.

CH 541A NUCLEAR CHEMISTRY II (3-4). A continuation of CH 540A with emphasis on techniques peculiar to chemical studies of radioactive materials; methods of isolation, purification and analysis of mixtures. TEXT: Friedlander and Kennedy, *Nuclear and Radiochemistry.* PREREQUISITE: CH 540A.

CH 551A RADIOCHEMISTRY I (2-4). Discussion of important aspects of radioactivity from standpoint of the chemical transformations which accompany it and which it may induce; techniques for measurement and study of ionizing radiation; methods of separation of unstable nuclides, identification and assay. TEXT: Friendlander and Kennedy, *Nuclear and Radiochemistry.* PREREQUISITES: CH 109D or CH 107D; and PH 638B.

CH 552A RADIOCHEMISTRY II (3-4). A discussion of chemical properties and behaviors of unstable elements. Topics considered are the formation and decay schemes of the more important unstable nuclides, methods of isolation and purification and analysis of mixtures; exchange reactions; chemical reactions that take place in consequence of nuclear reactions. TEXT: Friedlander and Kennedy, *Nuclear and Radiochemistry.*

CH 553B RADIOCHEMISTRY (2-4). A descriptive course with emphasis on nuclear reactions. The laboratory includes detection techniques and activation analysis employing the nuclear reactor. PREREQUISITE: NONE.

CH 554A RADIOCHEMISTRY, ADVANCED (2-3). An advanced course in radiochemical techniques and applications offered to well-qualified students only. Experiments in analysis of complex mixtures of active nuclides; activation analysis. Consent of the instructor required. PREREQUISITE: CH 551A or CH 541A.

CH 580A APPLIED ELECTROCHEMISTRY (3-2). Basic principles of electrochemistry. Electrolytic solutions, half-cell reactions, practical aspects of primary and secondary cells. Not open to students who have completed CH 444B. TEXTS: Daniels and Alberty, *Physical Chemistry;* Vinal, *Storage Batteries.* PREREQUISITE: CH 405B or CH 407B.

CH 581A PROPERTIES OF CERAMIC MATERIALS (4-0). Occurrence, syntheses and properties of ceramic raw materials. Kinetic and phase equilibrium principles underlying the production of ceramics and glasses. Structure of typical ceramics and glasses. TEXT: Kingery, *Introduction to Ceramics.* PREREQUISITES: Physical Chemistry and Thermodynamics.

CH 600C READING AND CONFERENCE IN CHEMISTRY (1-0 to 4-0). A closely supervised individual study to be pursued by students whose backgrounds or future plans require additional or exceptional treatment of material at the undergraduate level. PREREQUISITE: Permission of the instructor.

CH 800E CHEMISTRY SEMINAR (0-1). A departmental program in which invited speakers and resident faculty speak on current topics in chemistry and related areas. Mature students may be assigned topics from the literature or may be requested to report on their research. PREREQUISITE: Consent of the Instructor.

CH 850A SPECIAL TOPICS IN CHEMISTRY (Credit to be arranged). Pursuit of deeper understanding of some topic chosen by the student and the instructor; may involve directed reading and conference or a lecture pattern. May be repeated for credit with a different topic. PREREQUISITE: Permission of the Instructor.

CH 900E RESEARCH (0-2 to 0-10). Experimental investigation of original problems. PREREQUISITE: Permission of the professor in charge.

CRYSTALLOGRAPHY

Cr 271A CRYSTALLOGRAPHY AND X-RAY TECHNIQUES (3-2). The esential concepts of crystallography, the stereographic projection, modern x-ray diffraction and radiographic apparatus and techniques, the theory of x-ray diffraction, high temperature diffraction techniques. The laboratory work includes a study of crystal models for symmetry, forms, and combinations; the construction of stereographic projections; and actual practice in making and interpreting of x-ray diffraction photographs. TEXTS: Buerger, *Elementary Crystallography*; Azaroff and Buerger, *The Powder Method.* PREREQUISITE: CH 107D.

Cr 301B CRYSTALLOGRAPHY AND MINERALOGY (3-4). Designed primarily for the student who will continue with courses in mineralogy, geology, and petrology. The student is introduced to the fundamental concepts of crystallography, the stereographic projection, the theory of x-ray diffraction, and the application of x-ray powder methods as applied to identification of minerals. The laboratory work includes a study of crystal models, construction of stereographic projections, and determination of minerals by x-ray powder diffraction patterns. TEXT: Rogers, *Introduction to the Study of Minerals.* PREREQUISITE: CH 107D.

GEOLOGY

Ge 101C PHYSICAL GEOLOGY (3-2). The study of the various geological phenomena. Topics discussed are: rock-forming minerals; igneous, sedimentary, and metamorphic rocks; weathering and erosion; stream sculpture; glaciation; surface and sub-surface waters; volcanism, dynamic processes; structural geology; and interpretations of topographic maps. TEXT: Gilluly, *Principles of Geology.*

Ge 201B CRYSTALLOGRAPHY AND GEOLOGY (3-2). A course directed towards the specific needs of the Nuclear Engineering groups. About half the time is spent on modern concepts of crystallography including atomic bonding, lattices, point groups, space lattices, x-ray diffraction theory and techniques, polymorphism and isomorphism. Minerals, rocks, and physical geology are then covered with special emphasis on dynamic principles and seismology. TEXTS: Dana and Hurlburt, *Manual of Mineralogy;* Gilluly, *Principles of Geology.*

Ge 401B PETROLOGY AND PETROGRAPHY (2-3). The various igneous rock series on the basis of physical chemical theories; the characteristics, structures and textures of igneous rocks; the metamorphic rocks, mineral alteration metamorphism and the resultant rock types. The laboratory work consists of the study of the various rocks in hand specimens, and in thin sections under the petrographic microscope. The course is supplemented by trips to nearby localities. TEXTS: Pirsson and Knopf, *Rocks and Rock Minerals;* Grout, *Petrography and Petrology.* PREREQUISITE: CR 301B.

METALLURGY

Mt 021C ELEMENTS OF MATERIALS SCIENCE I (3-2). An introduction to the science and application of engineering materials. The subject matter covers many of the principles underlying the properties and behavior of materials, including atomic and crystal structure, mechanical properties and phase equilibria. PREREQUISITE: A course in general chemistry.

Mt 022C ELEMENTS OF MATERIALS SCIENCE II (3-2). A continuation of Mt 021C in which basic principles are applied in studying the properties, application, fabrication and corrosion of metals and other materials. PREREQUISITE: Mt 021C.

Mt 101C PRODUCTION METALLURGY (3-0). A course designed to familiarize the student with the nature, sources, and strategic aspects of metallurgical raw materials, and with modern methods of extracting and fabricating metals and alloys. Emphasis is directed at the effects of process variables on ultimate performance in service. Satisfies requirement in production metallurgy for degree in materials science or engineering.

Mt 102C PRODUCTION OF STEEL (3-0). A discussion of the occurrence and composition of various iron ores, blast furnace products, the various methods of steel production, and the production of grey, white and maleable cast iron. TEXT: Bray, *Ferrous Process Metallurgy.* PREREQUISITE: General Chemistry.

Mt 103C PRODUCTION OF NON-FERROUS METALS (3-0). A discussion of the sources, the strategic importance

of, and the methods of production of copper, zinc, lead, tin, aluminum, magnesium, and other metals of technical interest. TEXT: Bray, *Non-Ferrous Production Metallurgy.* PREREQUISITE: General Chemistry.

Mt 104C PRODUCTION METALLURGY (4-0). A condensation of the material of Mt 102C and Mt 103C into a one-term course. TEXTS: Bray, *Non-Ferrous Production Metallurgy;* Bray, *Ferrous Process Metallurgy.* PREREQUISITE: General Chemistry.

Mt 201C ENGINEERING MATERIALS I (3-2). Principles underlying the properties and behavior of materials which make them useful in structures, machines, and devices, including atomic arrangements and imperfections in crystalline and non-crystalline phases; equilibrium and non-equilibrium phase relationships in one-, two-, and three-component systems; elasticity and fracture; recovery, recrystallization, and grain growth; mechanisms and kinetics of diffusion and phase transformation; chemical behavior and corrosion. Introduction to metallic, ionic, and polymeric materials to correlate structure with properties in illustrating the above subjects. TEXT: Clark and Varney, *Physical Metallurgy for Engineers,* 3rd ed., 1962. PREREQUISITES: General Chemistry, General Physics.

Mt 202C ENGINEERING MATERIALS II (3-2). Extension of the principles of materials science to the metallic state; nucleation and growth; diffusion-controlled and diffusionless transformation; heat treatment and hardenability; thermal and transformation stresses; relaxation processes; quench aging and strain aging; engineering alloy systems including iron, steel, alloy steels, stainless steels, PH stainless steels, high temperature alloys; corrosion problems. TEXT: Clark and Varney, *Physical Metallurgy for Engineers,* 2nd ed., 1962. PREREQUISITE: Mt 201C.

Mt 203B PHYSICAL METALLURGY (Special Topics) (2-2). A continuation of material presented in Mt 201C and Mt 202C, including a discussion of powder metallurgy, welding and casting, fatigue, properties of metals at low temperatures, and surveys of the alloys of aluminum and magnesium. TEXTS: Coonan, *Principles of Physical Metallurgy;* Heyer, *Engineering Physical Metallurgy;* Clark and Varney, *Physical Metallurgy for Engineers;* Woldman, *Metal Process Engineering.* PREREQUISITE: Mt 202C.

Mt 204A NON-FERROUS METALLOGRAPHY (3-3). An expansion of material introduced in Mt 201C, Mt 202C and Mt 203B with greater emphasis on the intrinsic properties of specific non-ferrous metals and alloys. PREREQUISITE: Mt 202C.

Mt 205A ADVANCED PHYSICAL METALLURGY (3-4). The subject matter includes equilibrium in alloy systems, the crystallography of metals and alloys, phase transformations and diffusion. The laboratory time is devoted to x-ray techniques used in metallurgical studies. TEXTS: Barrett, *Structure of Metals;* Cullity, *Elements of X-ray Diffraction;* Rhines, *Phase Diagrams in Metallurgy.* PREREQUISITE: Mt 202C, PH 620B or equivalent.

Mt 206A ADVANCED PHYSICAL METALLURGY (3-4). The subject matter is an extension of that offered in Mt 205A but is primarily concerned with dislocations and other imperfections and their influences on the physical properties of metals. TEXTS: Cottrell, *Dislocation and Plastic Flow in Crystals;* Read, *Dislocation in Crystals.* PREREQUISITE: Mt 205A.

Mt 207B PHYSICS OF SOLIDS (3-0). A course for engineers intended as an introduction to the physics of solids. Topics discussed include introductory statistical mechanics, atomic structure and spectra, introductory quantum mechanics, binding and energy bands, crystal structure and imperfections in crystals. TEXT: Sproull, *Modern Physics.* PREREQUISITE: Mt 202C.

Mt 208B PROPERTIES OF MATERIALS (3-2). This course is designed for the specific needs of the aeronautical engineer, and includes the effects of various mechanical and thermal treatments on the structures and properties of aircraft and space materials including steels, titanium, aluminum, magnesium, and other alloys. Discussion of corrosion and oxidation-resisting materials, including chromium-nickel stainless steels, precipitation hardening alloy steels, ceramics, cermets, and plastics. A correlation of the foregoing principles with corrosion, creep, and fatigue type failures. TEXT: Clark and Varney, *Physical Metallurgy for Engineers,* 2nd ed., 1962. PREREQUISITE: Mt 201C.

Mt 212C PHYSICAL AND PRODUCTION METALLURGY (4-2). This course covers the same material as Mt 202C and includes in addition the production of iron and steel. One period each week is devoted to this latter topic. TEXTS: Coonan, *Principles of Metallurgy;* Bray, *Ferrous Process Metallurgy;* Clark and Varney, *Physical Metallurgy for Engineers.* PREREQUISITE: Mt 201C.

Mt 221B PHASE TRANSFORMATIONS (3-0). Kinetics, thermodynamics and mechanisms of nucleation and growth; solidification, precipitation, recrystallization, martensitic transformations, eutectoid transformations and order-disorder phenomena. PREREQUISITE: Mt 202C.

Mt 222A MECHANICAL PROPERTIES OF SOLIDS (3-0). Elements of elastic and plastic deformations; discussion of mechanical properties; deformation and fracture in single crystal and polycrystalline metals; the effect of temperature; the correlation of mechanical properties and phenomena with microstructures and imperfections. PREREQUISITE: Mt 202C.

Mt 223A MATERIALS FOR ELECTRICAL AND ELECTRONIC APPLICATIONS (3-0). The fundamental principles underlying the electrical, electronic, and magnetic properties of solids. Perfect and imperfect crystals; non-crystalline materials. The nature and properties of conductors, semiconductors, insulators and magnetic materials. The relation between structure and properties; the effect of impurities and of fabrication. Theoretical aspects are illustrated by describing typical materials. PREREQUISITE: A course in introductory materials science or equivalent.

Mt 302C ALLOY STEELS (3-0). A study of the effects of alloying elements including carbon commonly used in steel making, plus precipitation hardening and dispersion hardening effects. Descriptive material includes super high strength alloys, high temperature alloys, corrosion resistant alloys. TEXT: E. C. Bain, *The Alloying Elements in Steel.* PREREQUISITE: Mt 202C.

Mt 303A METALLURGY SEMINAR. Hours to be arranged. Papers from current technical journals will be reported on and discussed by students. PREREQUISITE: Mt 203B or Mt 205A.

Mt 304A SPECIAL TOPICS IN MATERIALS SCIENCE (credit by arrangement). An advanced course in which theoretical and practical problems of materials properties, applications and fabrication are discussed. PREREQUISITE: Consent of Instructor.

Mt 307A HIGH TEMPERATURE STUDIES (0-3). A laboratory course designed to familiarize the student in the study of fundamentals at high temperatures. Students working in small groups will be given an opportunity to undertake some original investigation with the purpose of developing an understanding of problems involved and methods of analysis in high temperature studies of materials. PREREQUISITES: Mt 221B, Mt 222A.

Mt 312A MATERIALS SYSTEMS FOR ADVERSE ENVIRONMENTS (4-0). Discussion of environmental factors such as temperature, corrosion, thermal and mechanical shock, vibration, and sustained loading. Response of materials to environmental factors. Characteristics of metallic alloy systems, ceramics, plastics, and composite materials as they relate to performance under adverse conditions. TEXT: To be selected. PREREQUISITE: Mt 202C or Mt 208B.

Mt 401A PHYSICS OF METALS (3-0). A discussion of crystal chemistry and modern theories of the solid state. TEXTS: Kittrell, *Solid State Physics;* selected references. PREREQUISITES: Mt 205A or PH 640.

Mt 402B NUCLEAR REACTOR MATERIALS — EFFECTS OF RADIATION (3-0). A course designed for students in nuclear engineering. Includes a study of materials of reactor construction; factors in materials selection; commercially available materials; liquid metal coolants; nature of radiation damage on materials. TEXTS: *The Reactor Handbook—General Properties Materials;* Finniston and Howe, *Metallurgy and Fuels;* Drenes and Vineyard, *Radiation Effects in Solids.* PREREQUISITE: Mt 207B, or equivalent.

Mt 403B CORROSION AND CORROSION PROTECTION (3-2). A course designed to give a knowledge of the chemical and electromechanical mechanism of corrosion and the environmental and stress factors that affect the rate of corrosion. Methods of control such as cathodic protection, alloying, protective coatings, and inhibitors will be considered. TEXT: Uhlig, *Corrosion and Corrosion Control.* PREREQUISITE: General Chemistry.

Mt 501A WELDING METALLURGY (3-3). A study of the various materials equipment and processes employed for joining metals by both the plastic and the fusion welding methods, and of the mechanical, electrical, and metallurgical factors essential to successful welding. PREREQUISITE: Mt 203B.

Mt 900E RESEARCH (0-2 to 0-10). Experimental investigation of original problems. PREREQUISITE: Consent of Instructor.

DEPARTMENT OF MATHEMATICS

WARREN RANDOLPH CHURCH, Professor of Mathematics and Mechanics; Chairman (1938)*; B.A., Amherst, 1926; M.A., Univ. of Pennsylvania; 1930; Ph.D., Yale Univ., 1935.

CHARLES HENRY RAWLINS, JR., Professor Emeritus of Mathematics and Mechanics (1922); Ph.B., Dickinson College, 1910; M.A., 1913; Ph.D., Johns Hopkins Univ., 1916.

RICHARD D. AMORE, Ensign, U.S. Navy; Instructor of Mathematics (1965); B.S., Univ. of Scranton, 1964; M.S., Bucknell Univ., 1965.

HORACE CROOKHAM AYRES, Professor of Mathematics and Mechanics (1958); B.S., Univ. of Washington, 1931; M.S., 1931; Ph.D., Univ. of California, 1936.

WILLARD EVAN BLEICK, Professor of Mathematics and Mechanics (1946); M.E., Stevens Institute of Technology, 1929; Ph.D., Johns Hopkins Univ., 1933.

RICHARD CROWLEY CAMPBELL, Professor of Mathematics and Mechanics (1948); B.S., Muhlenberg College, 1940; M.A., Univ. of Pennsylvania,, 1942.

DONALD MACALLISTER FAIRBAIRN, Ensign, U.S. Naval Reserve; Instructor of Mathematics (1964); B.S., George Peabody College, 1963.

FRANK DAVID FAULKNER, Professor of Mathematics and Mechanics (1950); B.S., Kansas State Teachers College, 1940; M.S., Kansas State College, 1942.

JOSEPH GIARRATANA, Professor of Mathematics and Mechanics (1946); B.S., Univ. of Montana, 1928; Ph.D., New York Univ., 1936.

EUGENE H. HANSON, Visiting Professor of Mathematics (1962); B.S., Denison Univ., 1925; M.A., Ohio State Univ., 1933; Ph.D., 1935.

HERBERT J. HAUER, Assistant Professor of Mathematics and Mechanics (1963); B.S., Queens College, 1949; M.A., Univ. of California, 1955.

WALTER JENNINGS, Professor of Mathematics and Mechanics (1947); B.A., Ohio State Univ., 1932; B.S., 1932; M.A., 1934.

WILLIAM JOSEPH KENNEDY, JR., Lieutenant Junior Grade, U.S. Naval Reserve; Instructor of Mathematics (1963); B.A., Whitman College, 1960.

UNO ROBERT KODRES, Associate Professor of Mathematics and Mechanics (1963); B.A., Wartburg College, 1954; M.S., Iowa State Univ., 1956; Ph.D., 1958.

ERIC S. LANGFORD, Assistant Professor of Mathematics (1964); B.S., Massachusetts Institute of Technology, 1959; M.S., Rutgers Univ., 1960; Ph.D., 1963.

HAROLD JOSEPH LARSON, Associate Professor of Mathematics (1962); B.S., Iowa State Univ., 1956; M.S., 1957; Ph.D., 1960.

BROOKS JAVINS LOCKHART, Professor of Mathematics and Mechanics (1948); B.A., Marshall Univ., 1937; M.S., West Virginia Univ., 1940; Ph.D., Univ. of Illinois, 1943.

KENNETH ROBERT LUCAS, Associate Professor of Mathematics (1958); B.S., Washburn Univ., 1949; Ph.D., Kansas Univ., 1957.

HERMAN BERNHARD MARKS, Associate Professor of Mathematics (1961); B.S., Southern Methodist Univ., 1950; M.A., Univ. of Texas, 1959.

HUGO M. MARTINEZ, Associate Professor of Mathematics (1964); B.A., Univ. of California, 1952; M.S., Stanford Univ., 1961; Ph.D., Univ. of Chicago, 1963.

ALADUKE BOYD MEWBORN, Professor of Mathematics and Mechanics (1946); B.S., Univ. of Arizona, 1927; M.S., 1931; Ph.D., California Institute of Technology, 1940.

PAUL ROBERT MILCH, Assistant Professor of Mathematics (1963); B.S., Brown Univ., 1958.

ROBERT R. PEARSON, Lieutenant, U.S. Naval Reserve; Instructor in Mathematics (1963); B.A., Univ. of Connecticut, 1959.

ROBERT MERLIN PICKRELL, Commander, U.S. Navy; Instructor of Mathematics (1963); B.S., U.S. Naval Academy, 1945.

JOHN PHILIP PIERCE, Professor of Mathematics (1948); B.S. in E.E., Worcester Polytechnic Institute, 1931; Master of E.E., Polytechnic Institute of Brooklyn, 1937.

FRANCIS MCCONNELL PULLIAM, Professor of Mathematics and Mechanics (1949); B.A., Univ. of Illinois, 1937; M.A., 1938; Ph.D., 1947.

ROBERT RICHARD READ, Associate Professor of Mathematics (1961); B.S., Ohio State Univ., 1951; Ph.D., Univ. of California, 1957.

PAUL C. ROGERS, Lieutenant Commander, U.S. Naval Reserve; Visiting Assistant Professor of Mathematics (1961); B.N.S., College of Holy Cross, 1945; M.A., Boston Univ., 1948.

GEORGE DONALD SCHMEIG, Ensign, U.S. Naval Reserve; Instructor of Mathematics (1963); B.A., Univ. of South Dakota, 1963.

ELMO JOSEPH STEWART, Professor of Mathematics (1955); B.S., Univ. of Utah, 1937; M.S., 1939; Ph.D., Rice Institute, 1953.

CHARLES CHAPMAN TORRANCE, Professor of Mathematics and Mechanics (1946); M.E., Cornell Univ., 1922; M.A., 1927; Ph.D., 1931.

THURMAN BADER WENZL, Ensign, U.S. Navy; Instructor of Mathematics (1965); B.S., Rensselaer Polytechnic Institute, 1963; M.S., Univ. of Virginia, 1965.

FRANK M. WILLIAMS, Assistant Professor of Mathematics (1965); B.S., New Mexico State Univ., 1958; M.S., 1960; Ph.D., 1963.

Richard P. Woodring, Lieutenant, U.S. Naval Reserve; Instructor in Mathematics (1964); B.A., Washington and Jefferson College, 1957; M.S., Univ. of Utah, 1959.

Walter Max Woods, Associate Professor of Mathematics (1961); B.S., Kansas State Teachers College, 1951; M.S., Univ. of Oregon, 1957; Ph.D., Stanford Univ., 1961.

Peter William Zehna, Associate Professor of Mathematics (1961); B.A., Colorado State College, 1950; M.A., 1951; M.A., Univ. of Kansas, 1956; Ph.D., Stanford Univ., 1959.

*The year of joining the Postgraduate School faculty is indicated in parentheses.

DEGREES WITH MAJOR IN MATHEMATICS

Officer students may, under special conditions, be offered the opportunity to qualify for either a Bachelor of Science or Master of Science degree with major in mathematics. Any interested student should consult the Chairman of the Department of Mathematics and Mechanics for an evaluation of his previous work to determine his potential for obtaining either degree and to consider the possibility of scheduling the necessary work. Evaluation of courses presented upon entering the Postgraduate School for credit toward these degrees must be completed prior to entering a program leading to these degrees. The requirements in mathematics for these degrees are given below. They provide, on the bachelor's or master's level, a working knowledge of one field of mathematics and a well-rounded background in three of the major fields of mathematics.

1. Requirements for the degree of *Bachelor of Science* with major in Mathematics.

a. Of the total term hours specified in the general requirements for the degree of Bachelor of Science, a student majoring in mathematics must complete at least 36 term hours of approved course work in mathematics beyond the calculus, and must have an average QPR of 1.25 or better in these 36 term hours.

b. These 36 term hours in mathematics must include at least 6 hours of approved course work in each of three fields of mathematics and two of these fields must be analysis and algebra.

c. Each student majoring in mathematics will set up in advance, in consultation with the Chairman of the Department, and approved by him, a mathematics curriculum fitted to his aims, aptitudes, preparation, and interests. This original curriculum may, however, be modified as work progresses, but only in consultation with and with the approval of the Chairman of the Department.

2. Requirements for the degree of *Master of Science* with major in Mathematics.

a. A student pursuing a program leading to a Master of Science degree with major in mathematics must have completed work which would qualify him for a Bachelor of Science degree with major in mathematics as defined in paragraph 1. A student whose background does not satisfy this requirement may take course work to eliminate this deficiency while simultaneously pursuing the Master of Science Program. However, course work pursued to eliminate this deficiency cannot be counted toward satisfying either the general or departmental requirements for the degree of Master of Science.

b. Of the total term hours specified in the general requirements for the degree of Master of Science, a student majoring in mathematics must complete at least 24 term hours of approved A or B level course work in mathematics, and must have an average QPR of 2.125 or better in these 24 term hours. These 24 term hours must include at least 6 hours in each of the fields of analysis and algebra. Each student majoring in mathematics will set up in advance, in consultation with the Chairman of the Department, and approved by him, a mathematics curriculum fitted to the student's aims, aptitudes, preparation and interests. This original curriculum may, however, be modified as work progresses, but only in consultation with and with the approval of the Chairman of the Department.

c. A student pursuing a program leading to the degree of Master of Science with major in mathematics will be required to write a thesis in Mathematics. The nature of the thesis may but need not be an original contribution to knowledge. The purpose of the thesis is to demonstrate the student's ability to recognize a problem, define that problem, investigate and successfully complete various facets of the problem and then be able to document and present his work on the problem. For the completion of the thesis the student will be given 8 hours credit, which will be in addition to the required 24 hours.

d. In addition to the above requirements, a student must pass a written comprehensive examination in mathematics. This examination is given twice each year and normally a student will take his examination within the year preceding the award of the Master of Science degree.

3. The thesis director, topic, and subject of specialization shall be chosen, with the consent of the chairman of the department, as early as possible (but in all events, not later than two terms prior to the time for granting the degree). Minor departures from the preceding requirements may he authorized by the Chairman of the Department of Mathematics and Mechanics.

MATHEMATICS

Ma 000E, Ma 001E PROBLEM SESSION (0-1). Non credit problem session to supplement other courses.

Ma 010D BASIC ALGEBRA AND TRIGONOMETRY I (4-0). Review of arithmetic processes. The real number

system. Engineering notation and the slide rule. Algebraic operations. Linear equations. Graph. Laws of exponents. Quadratic equations; the quadratic formula. Logarithms. Definition of trigonometric functions. Solution of the right triangle. PREREQUISITE: None.

Ma 025D ELEMENTARY SETS WITH APPLICATIONS (3-0). Study of the vital role played by set theory throughout contemporary mathematics. A brief introduction to naive set theory is followed by an elementary treatment of logic and the nature of mathematical proof. Techniques of informal proof are implemented in proving standard theorems about sets. Following a study of relation and function as an application of set theory a Boolean algebra is defined and used to summarize the algebra of both sets and logic. A final application is given through a systematic treatment of finite prohability theory from a set point of view. PREREQUISITE: None.

Ma 030D INTERMEDIATE ALGEBRA (5-0). The set of real numbers and postulates for the development of the algebra of real numbers. Proofs of some elementary theorems for the algebra of the real numbers. Applications of the postulates and theorems to addition, subtraction, multiplication, division and factorization of algebraic expressions. Application to word problems, first degree equations and equations of higher degree. Functions, graphs and inequalities. Exponents and logarithms. Sequences, series and the binomial theorem. Complex numbers. PREREQUISITE: None.

Ma 031D COLLEGE ALGEBRA AND TRIGONOMETRY (5-0). Brief review of algebraic fundamentals. Slide rule and logarithmic methods of computation. Algebra of complex numbers, quadratic equations. Systems of equations, determinants: Cramer's rule. Binomial Theorem. Mathematical induction. Trigonometric functions of the general angle. Identities. Solution of right and oblique triangles. Elements of the theory of equation. PREREQUISITES: Previous courses in College Algebra and Trigonometry.

Ma 051D CALCULUS AND ANALYTIC GEOMETRY I (5-0). Fundamentals of plane analytic geometry, concepts of function, limit, continuity. The derivative and differentiation of algebraic and trigonometric functions with applications. Derivatives of higher order. Differentials. Formal integration of elementary functions. Rolles' theorem, areas, volumes of revolution. PREREQUISITE: Ma 031D or its equivalent.

Ma 052D CALCULUS AND ANALYTIC GEOMETRY II (5-0). Selected topics from plane geometry. Differentiation and integration of transcendental functions. Hyperbolic functions. Parametric equations. Formal integration. Numerical integration. Improper integrals. Polar coordinates. Plane vectors. PREREQUISITE: Ma 051D.

Ma 053D CALCULUS AND ANALYTIC GEOMETRY III (5-0). Partial derivatives, directional derivatives, total differential. Chain rule differentiation. Introduction to vector analysis. Del operator. Line integrals. Multiple integration and applications. Introduction to infinite series. PREREQUISITE: Ma 052D.

Ma 071D CALCULUS I (5-0). The calculus of functions of a single independent variable with emphasis on basic concepts. Derivatives, differentials, applications, Rolles' theorem and the mean value theorem. Definite integral with applications. Elementary transcendental functions. Topics from plane analytic geometry to be introduced as necessary. Polar coordinates. PREREQUISITES: Ma 031D or its equivalent, and previous work in calculus.

Ma 072D CALCULUS II (5-0). Advanced transcendental functions including hyperbolic functions. Methods of formal integration. Numerical methods. Improper integrals. Partial derivatives, directional derivatives. Total differential. Chain rule differentiation. Introduction to vector analysis. Del operator. Line integrals. Multiple integrals with applications. PREREQUISITES: Ma 071D.

Ma 073C DIFFERENTIAL EQUATIONS (5-0). A continuation of Ma 072D. Series of constants; power series; Fourier series; first order ordinary differential equations; ordinary linear differential equations with constant coefficients; simultaneous solution of ordinary differential equation series solution of ordinary differential equations, including Bessel's Equation. PREREQUISITE: Ma 072D.

Ma 100B THEORY OF EQUATIONS (3-0). Polynomials in one variable, algebraic equations and their roots, rational roots, cubic and bi-quadratic equations, symmetric functions, approximate evaluation of roots. PREREQUISITE: Calculus.

Ma 101B LINEAR ALGEBRA I (3-0). Systems of Linear Equations. Vector Spaces. Algebra of Matrices. Determinants. PREREQUISITE: Consent of Instructor.

Ma 102B LINEAR ALGEBRA II (3-0). Bilinear and Quadratic Forms. Linear Transformation on a Vector Space. Canonical Representations of a Linear Transformation. PREREQUISITE: Ma 101B.

Ma 103C PROJECTIVE GEOMETRY (3-0). Transformations in Euclidean geometry; invariants; perspectivities; Desargue's triangle theorems; principle of duality; homogeneous coordinates of points and lines; linear combinations of points and lines; cross ratio, a projective invariant; harmonic division, properties of complete quadrangles and complete quadrilaterals; projective transformations, the projective properties. PREREQUISITE: Consent of Instructor.

Ma 104A ALGEBRAIC CURVES (3-0). An introduction to study of algebraic geometry is given by means of a solution of topics from the theory of curves, centering around birational transformations and linear series. PREREQUISITES: Ma 103C and Ma 105B or consent of Instructor.

Ma 105B FUNDAMENTALS OF MODERN ALGEBRA I (3-0). Concept of group; subgroups; composition of

groups; basic theorems for Abelian groups. Rings; integral domains; ideals; polynomial rings; basis theorems for rings. PREREQUISITE: Consent of Instructor.

Ma 106B FUNDAMENTALS OF MODERN ALGEBRA II (3-0). Continuation of Ma 105B. Fields; field extensions; algebraic numbers; algebraic integers; root fields and their Galois groups; properties of the Galois group and its sub-groups; finite fields; insolvability of the quintic polynomial. PREREQUISITE: Ma 105B.

Ma 107B INTRODUCTION TO GENERAL TOPOLOGY (3-0). Review of usual topology in *En* fundamentals of point set topology, e.g., compactness, connectivity, homeomorphism, etc. Hausdorff, metrizable, regular spaces, and embedding theorems. Applications. PREREQUISITE: Ma 109B or consent of Instructor.

Ma 109B FUNDAMENTALS OF ANALYSIS I (3-0). Elements of set theory and topology in E*n*; vector valued functions, differentials and Jacobians; functions of bounded variation. PREREQUISITE: Consent of Instructor.

Ma 110B FUNDAMENTALS OF ANALYSIS II (3-0). Theory of Reimann-Stieljes integration, multiple integrals, sequences and series of functions. PREREQUISITE: Ma 109B.

Ma 111A FUNDAMENTALS OF ANALYSIS III (3-0). Continuation of Ma 110B. Line and surface integrals, Stokes theorem, improper integrals, Fourier series and Fourier integrals. PREREQUISITES: Ma 109B and Ma 110B.

Ma 113B VECTOR ANALYSIS and PARTIAL DIFFERENTIAL EQUATIONS (4-0). Calculus of vectors; differential operators; line and surface integrals; Green's, Stokes, and divergence theorems. Separation of variables; boundary conditions; applications to heat flow. PREREQUISITES: Ma 120C, Ma 240C and Ma 251C.

Ma 116B MATRICES AND NUMERICAL METHODS (3-2). Finite differences, interpolation, numerical differentiation and integration; numerical solution of polynomial equations; numerical methods for initial value and boundary value problems involving ordinary and partial differential equations; solution of systems of linear algebraic equations; latent roots and characteristic vectors of matrices; numerical methods for inversion of matrices. PREREQUISITES: Ma 113B, or Ma 183B, or Ma 245B, or Ma 246B.

Ma 120C VECTORS AND MATRICES WITH GEOMETRIC APPLICATIONS (3-1). Real number system. Algebra of complex numbers. Vector algebra. Points, lines and planes in vector and scalar notation. Quadric surfaces. Matrices, determinants, linear systems and linear dependence. Laboratory periods devoted to a review of essential topics in trigonometry and plane analytic geometry. PREREQUISITE: A course in plane analytic geometry.

Ma 125B NUMERICAL METHODS FOR DIGITAL COMPUTERS (2-2). Numerical solution of systems of linear algebraic equations, polynomial equations, and systems of non-linear algebraic equations; finite differences, numerical interpolation, differentiation, integration; numerical methods for solving initial value and boundary value problems involving ordinary and partial differential equations. PREREQUISITE: Ma 113B or Ma 183B, or Ma 245B or Ma 246B.

Ma 126B NUMERICAL METHODS FOR DIGITAL COMPUTERS (3-2). Lagrangian polynomial approximations to real functions. Introduction to best polynomial approximations in the sense of least squares. Minimax polynomial approximations. Numerical methods for solving equations and systems of equations. Difference calculus, numerical differentiation and integration. Selected numerical methods for solving initial value and boundary value problems involving ordinary and partial differential equations. The laboratory periods include sample problems solved on hand-operated keyboard calculators; emphasis is given to methods which are useful with large scale automatic digital computers. PREREQUISITE: Ma 240C or equivalent.

Ma 128B NUMERICAL METHODS IN PARTIAL DIFFERENTIAL EQUATIONS (3-1). Finite difference expressions for derivatives. Boundary value problems in ordinary differential equations. Iterative methods for solving systems of linear algebraic equations. Relaxation methods. Basic numerical methods for linear second order partial differential equations of Laplace, Poisson, heat-flow and the one-dimentional wave equation. Introduction to difference equations. Stability. Discretization and round-off errors. PREREQUISITES: Ma 125B and Ma 421C.

Ma 140B LINEAR ALGEBRA AND MATRIX THEORY (4-0). Systems of linear equations, equalities and inequalities. Vector spaces, bases. Determinants and matrices. Linear transformations, bilinear and quadratic forms. Canonical representations. Geometrical interpretations. Latent roots and vectors of a matrix. PREREQUISITE: Ma 141D or the equivalent.

Ma 141D REVIEW OF ANALYTIC GEOMETRY AND CALCULUS (5-0). Cartesian coordinates; analytical geometry of straight line and second degree curves. Trigonometry. Concepts of function, limit and continuity. Differential and integral calculus. Functions of several variables. Algebra and the theory of equations. Inequalities. PREREQUISITE: Previous course in analytic geometry and calculus.

Ma 146B NUMERICAL ANALYSIS AND DIGITAL COMPUTERS (3-0). Finite differences. Interpolation and function representation. Difference equations. Numerical integration. Algebraic and transcendental equations. Matrix manipulation: linear simultaneous algebraic equations, latent roots and vectors of matrices. (Computer methods will be emphasized throughout.) PREREQUISITE: Ma 140B.

Ma 150C VECTORS AND MATRICES WITH GEOMETRIC APPLICATIONS (4-1). Real number system. Algebra of complex numbers. Vector algebra. Points, lines and planes in scalar and vector notation. Special Surfaces.

Frenet-Serret formulae. Directional derivatives, gradient and curl. Determinants, matrices, linear systems and linear dependence. Laboratory periods devoted to review of essential topics in trigonometry and plane geometry. PREREQUISITE: A course in plane analytic geometry.

Ma 151C DIFFERENTIAL EQUATIONS (4-1). Review of calculus. Partial derivatives. Polar coordinates and change of variables. Elements of differential equations; first order; linear, total; systems of linear equations. PREREQUISITE: A course in differential and integral calculus.

Ma 158B COMPLEX VARIABLES AND LAPLACE TRANSFORMS (4-0). Analytic functions. Cauchy's theorem and formula. Taylor and Laurent series, residues, contour integration, conformal mapping. The Laplace transform and its use in solving ordinary differential equations; inversion integral. Systems of linear differential equations. Stability criteria. PREREQUISITES: Ma 120C and Ma 151C.

Ma 180C VECTORS, MATRICES, AND VECTOR SPACES (3-1). Real number system. Algebra of complex numbers. Vector algebra. Points, lines, and planes in scalar and vector notation. Matrices, determinants, and linear systems. Abstract vector spaces. Laboratory periods devoted to a review of essential topics in trigonometry and analytic geometry. PREREQUISITE: Consent of Instructor.

Ma 181D PARTIAL DERIVATIVES AND MULTIPLE INTEGRALS (4-1). Review of elementary calculus. Hyperbolic functions. Infinite series. Partial and total derivatives. Directional derivatives and gradients and their physical interpretation. Jacobians. Leibnitz's Theorem for differentiating integrals. Line integrals. Double and triple integrals. PREREQUISITES: A course in differential and integral calculus and Ma 120C to be taken concurrently.

Ma 182C DIFFERENTIAL EQUATIONS AND VECTOR ANALYSIS (5-0). Differential equations. Series solutions of ordinary differential equations. Systems of differential equations, including matrix methods. Vector differentiation. Vector integral relations. PREREQUISITE: Ma 181D.

Ma 183B FOURIER SERIES AND COMPLEX VARIABLES (4-0). Expansion of functions. Fourier series and solution of partial differential equations. Algebra of complex numbers. Analytic functions of a complex variable, and the elementary transcendental functions. Complex integration. Residues. PREREQUISITE: Ma 182C.

Ma 193C SET THEORY AND INTEGRATION (2-0). Set theoretic concepts. Basic concepts in the theories of Riemann, Lebesgue, and Stieltjes integrals with emphasis on applications to probability theory. PREREQUISITE: Ma 181D or the equivalent.

Ma 196B MATRIX THEORY (3-0). Algebra of matrices; characteristic value of matrices; Hamilton-Cayley and Sylvester's theorems; Matrix methods in the solution of systems of differential equations. PREREQUISITE: Ma 120C or Ma 150C, or the equivalent.

Ma 220C PARTICLE DYNAMICS (2-2). Review of vector algebra and statics. Moment of a force about a point and about an axis. Axial and polar vectors. Reduction of a general force system and Poinsot's central axis. Centroids. Vector kinematics referred to a rotating coordinate frame. The Coriolis theorem and application to curvilinear coordinates. Potential energy and stability. Particle dynamics. PREREQUISITE: A previous course in mechanics.

Ma 230D CALCULUS OF SEVERAL VARIABLES (4-0). Review calculus of one variable. Taylor series, Leibnitz and L'Hospitals rules. Differential calculus of functions of several variables, directional derivatives, gradient vectors, geometry of tangent planes to surfaces. Double and triple integration in rectangular coordinates. PREREQUISITE: A previous course in calculus and Ma 120C or Ma 150C (may be taken concurrently).

Ma 240C ELEMENTARY DIFFERENTIAL EQUATIONS (2-0). Elements of differential equations including basic types of first order equations and linear equations of all orders with constant coefficients. Systems of linear equations. PREREQUISITE: Ma 230D (may be taken concurrently).

Ma 241C ELEMENTARY DIFFERENTIAL EQUATIONS (3-0). A longer version of Ma 240C including more emphasis on first order equations. PREREQUISITE: Ma 230D (may be taken concurrently).

Ma 244C ELEMENTARY DIFFERENTIAL EQUATIONS AND INFINITE SERIES (4-0). An abbreviated version of Ma 073C not including series solution of differential equations. PREREQUISITE: Ma 230D.

Ma 245B PARTIAL DIFFERENTIAL EQUATIONS (3-0). Solution of boundary value problems by separation of variables; Sturm-Liouville theory; Fourier Bessel series solution. PREREQUISITES: Ma 251C and Ma 240C.

Ma 246B PARTIAL DIFFERENTIAL EQUATIONS (4-0). Series solution of linear differential equations, generalized orthogonal functions; solution of boundary value problems by separation of variables; Sturm-Liouville theory; Fourier-Bessel series solutions. PREREQUISITE: Ma 240C.

Ma 248B DIFFERENTIAL EQUATIONS FOR OPTIMUM CONTROL (3-0). Methods in differential equations for calculating differentials based on the adjoint system of differential equations. Applications to problems in optimum control, particularly trajectories and minimum time problems. Numerical methods for determining and correcting trajectories, particularly optimum trajectories, on a digital computer. PREREQUISITES: Ma 240C or equivalent, and Ma 421C or consent of Instructor.

Ma 251C ELEMENTARY INFINITE SERIES (3-0). Sequences, series, convergence tests, Taylor's series, Fourier series, series solution of linear differential equations. Bessel and Legendre functions. PREREQUISITES: Ma 230D and Ma 240C.

Ma 252C SERIES AND DIFFERENTIAL EQUATIONS (4-0). Sequence and series; convergence tests; power series, Taylor series expansions; uniform convergence; first order differential equations and linear equations with constant coefficients; systems of linear equations. PREREQUISITE: Ma 230D (may be taken concurrently).

Ma 253C DIFFERENTIAL EQUATIONS AND SERIES (3-0). Series solutions of differential equations; Fourier series; solution of boundary value problems in terms of Fourier series; Legendre polynomials and Bessel functions. PREREQUISITE: Ma 252C.

Ma 254C TAYLOR AND FOURIER SERIES (3-0). Sequences and series; power series; Taylor series expansions; uniform convergence; Fourier series. PREREQUISITE: Ma 230D.

Ma 255C DIFFERENTIAL EQUATIONS AND SERIES SOLUTIONS (3-0). First order differential equations; linear equations with constant coefficients; systems of linear equations; series solutions of differential equations; separation and solution of boundary value problem equations in terms of Fourier series, Legendre and Bessel functions. PREREQUISITE: Ma 254C (may be taken concurrently).

Ma 260C VECTOR ANALYSIS (3-0). Vector differential and integral calculus including differential geometry of lines and surfaces, line and surface integrals, change of variable formulas and curvilinear coordinates. PREREQUISITES: Ma 120C and Ma 230D.

Ma 261B VECTOR MECHANICS (5-0). Line, surface and volume integrals, Green's divergence, and Stokes' theorems. Vector differential calculus, and the vector differential operators in rectangular and curvilinear coordinates. The integral theorems in vector form. The vector equations of motion. Irrotational, solenoidal and linear vector fields with applications to fluid mechanics in meteorology. Total differential equation and systems of total differential equations. PREREQUISITES: Ma 240C and Ma 251C.

Ma 270C COMPLEX VARIABLES (3-0). Analytic functions; series expansion; integration formulas; residue theory. PREREQUISITES: Ma 120C, Ma 230D

Ma 271C COMPLEX VARIABLES (4-0). A longer version of Ma 270C including more emphasis on Contour integration as required for transform theory. PREREQUISITES: Ma 120C, Ma 230D.

Ma 280B LAPLACE TRANSFORMATIONS (2-0). Definitions and existence conditions; applications to systems involving linear differences, differential and integral equations; inversion integral. PREREQUISITES: Ma 240C and Ma 270C, (the latter may be taken concurrently).

Ma 301C BASIC PROBABILITY AND SET THEORY (4-0). Elements of set theory and set algebra. Axioms for a probability function and models for finite sample spaces. Random variables and their probability distributions. Families of distributions and their characteristics. Chebyshev's inequality and the law of large numbers. Normal family and normal approximations. PREREQUISITE: A course in differential and integral calculus.

Ma 302B SECOND COURSE IN PROBABILITY (3-2). A continuation of Ma 301C. Jointly distributed random variables and the distribution of functions of random variables. Independence and conditional distributions. Sums of random variables and the Central Limit Theorem. PREREQUISITES: Ma 301C and Ma 181D or the equivalent.

Ma 303B THEORY AND TECHNIQUES IN STATISTICS I (3-2). Descriptive statistics. Point estimation. Principles of choice and properties of estimators. Methods for calculation. Confidence intervals. Applications. Testing hypotheses. Concepts of power, most powerful tests. Applications. PREREQUISITE: Ma 302B.

Ma 304B THEORY AND TECHNIQUES IN STATISTICS II (3-0). A continuation of Ma 303B. Regression and correlation. Least squares. Elements of analysis of variance. Multiple comparisons. Sequential sampling. Quality control. Sampling inspection. PREREQUISITE: Ma 303B.

Ma 305A DESIGN OF EXPERIMENTS (3-1). Theory of the general linear hypothesis. Analysis of variance. Planning of experiments. Randomized blocks and Latin Squares. Simple factorial experiments. PREREQUISITE: Ma 304B or consent of Instructor.

Ma 306A SELECTED TOPICS IN ADVANCED STATISTICS I (3-1). Topics will be selected by instructor to fit the needs and background of the students. Areas of choice to include the fields of sequential analysis, nonparametric methods and multivariate analysis. The course may be repeated for credit if the topic changes. PREREQUISITE: Ma 304B, or consent of Instructor.

Ma 307A STOCHASTIC PROCESS I (3-0). Poisson and Wiener processes. Markov chains. Discrete and continuous parameter cases. Ergodic properties and passage probabilities. Birth and death processes and their application to queueing theory. PREREQUISITE: Ma 304B or consent of the Instructor.

Ma 308A STOCHASTIC PROCESS II (3-0). Orthogonal representation of stochastic processes. Stationary time series; harmonic analysis of the auto correlation function. Ergodic properties. Applications. PREREQUISITE: Ma 307A.

Ma 309A SELECTED TOPICS IN ADVANCED STATISTICS II (3-0). A continuation of Ma 306A. PREREQUISITE: Ma 306A.

Ma 310C ELEMENTARY PROBABILITY AND STATISTICS (4-0). An introduction to probability and statistics. Methods of data summary. Tests of hypotheses and estimation. This course is limited to students in the BA/BS Program. PREREQUISITE: A previous course in college algebra.

Ma 311C INTRODUCTION TO PROBABILITY AND STATISTICS (4-1). An elementary treatment of probability with some statistical applications. Topics discussed are probability models, discrete and continuous random variables, moment properties, testing statistical hypotheses, and statistical estimation. PREREQUISITE: Ma 031D or equivalent.

Ma 315C INTRODUCTION TO PROBABILITY AND STATISTICS (4-2). Elements of set theory. Foundations of probability and basic rules of computation. Sample space, random variable, discrete and continuous distribution functions. Classical distribution functions. Limit theorems, Markov chains. Applications in fields of particular interest to class. PREREQUISITE: A previous course in calculus.

Ma 316B APPLIED STATISTICS I (3-2). Descriptive Statistics. Introduction to decision theory. Point estimation; principles of choice and properties of estimators; methods for calculation. Confidence intervals; applications. Testing hypotheses; concepts of power, most powerful tests; applications. PREREQUISITE: Ma 315C.

Ma 317B APPLIED STATISTICS II (3-0). A continuation of Ma 316B. Regression and correlation; least squares. Elements of Analysis of Variance; multiple comparison. Sequential sampling. Non-parametric procedure. PREREQUISITE: Ma 316B.

Ma 321B PROBABILITY (4-2). Elements of set theory. Foundations of Probability and basic rules of computation. Sample space, random variable, discrete and continuous distribution functions. The classical distribution functions. Joint, marginal and conditional distribution functions. Characteristic functions. Limit theorems. Introduction to random processes. Applications to fields of interest of the class. Markov chains. PREREQUISITES: Ma 244C and Ma 271C or the equivalent.

Ma 322A DECISION THEORY AND CLASSICAL STATISTICS (3-2). Testing statistical hypotheses, point estimation, interval estimation, regression analysis. Decision theoretic problem with specific attention given to minimax strategies. Bayes strategies, and admissibility. PREREQUISITE: Ma 321B and consent of Instructor.

Ma 326A ADVANCED PROBABILITY I (3-0). Probability viewed as a measure. Sets, measures and integration. Convergence almost surely, in probability and in quadratic mean. Distribution function and characteristic functions. PREREQUISITE: Consent of Instructor.

Ma 327A ADVANCED PROBABILITY II (3-0). Infinitely divisible laws. Strong and weak laws of large numbers. Classical central limit problems, modern central limit problems. PREREQUISITE: Consent of Instructor.

Ma 332B STATISTICS I (3-0). Introduction to probability theory. Derivation and properties of principal frequency functions of discrete and continuous random variables. Joint distributions and introduction to regression and correlation. PREREQUISITE: Ma 230D or the equivalent.

Ma 333B STATISTICS II (2-2). A continuation of Ma 332B. Applications of probability in statistics. Derived distributions. Estimators of parameters and their frequency functions. Mathematical expectation. Introduction to sampling theory. Applications in meteorology. PREREQUISITE: Ma 332B or the equivalent.

Ma 351B PROBABILITY AND STATISTICS (4-2). Elements of set theory. Foundations of probability and basic rules of computation. Sample space, random variable, discrete and continuous distribution functions. Bayes Theorem. The classical distribution functions. Expectations, propagation of error. Joint, Marginal, and conditional distribution functions, least squares. Limit theorems. Derivation of Poisson process. Elements of hypothesis testing and estimation. PREREQUISITE: Ma 230D.

Ma 352B APPLIED ENGINEERING STATISTICS (2-2). Tests of hypothesis and estimation. Analysis of variance. Statistical quality control, control charts. Sampling inspection. Reliability theory and application. PREREQUISITE: Ma 351B.

Ma 355A SYSTEM RELIABILITY AND LIFE TESTING (3-0). Reliability functions and their point and interval estimates under various sampling plans. Standard and accelerated life testing plans. Analysis of serial, parallel, and mixed systems. Analysis of reliability apportionment and inherent design reliability. Reliability growth models and methods for updating reliability estimates. Properties of functions with monotone failure rate. PREREQUISITES: Ma 303B and Ma 304B, or Ma 321B and Ma 322A.

Ma 371C MANAGEMENT STATISTICS (4-0). Elements of probability theory with emphasis on random variables and their probability distributions. Distributions of estimators of parameters. Applications of these concepts as aids in decision making. PREREQUISITE: Elementary Calculus.

Ma 381C ELEMENTARY PROBABILITY AND STATISTICS (4-2). Elements of the theory of probability. The classical probability distributions. Elements of statistical inference with applications in the field of the group. PREREQUISITE: Ma 181D or equivalent.

Ma 395B GAMES OF STRATEGY (3-2). Theory and applications of matrix games, including the minimax theorem, properties of optimal strategies, and solutions of some specific types of discrete games. Theory and applications of continuous games including games with convex kernels and games of timing. PREREQUISITE: Ma 196B or equivalent and Ma 301C or equivalent.

Ma 396A DECISION THEORY (3-0). Basic concepts. Bayes, admissible, minimax, and regret strategies. Principles of choice. Relation of statistical decision functions to the theory of games. Applications in the planning of operational evaluation trials. PREREQUISITES: Ma 304A, Ma 193C and Ma 395B. (The latter may be taken concurrently.)

Ma 397A THEORY OF INFORMATION COMMUNICATION (3-0). Markov chains; surprisal of events and uncer-

tainty of distributions: characterization of uncertainty; noise and rate of information transmission;limit distributions connected with sequences from an ergodic Markov chain; Shannan-Fano coding; detection. PREREQUISITES: Ma120C or Ma 150C and Ma 321B.

Ma 398B SAMPLING INSPECTION AND QUALITY CONTROL (3-1). Attribute and variables sampling plans. MIL. STD., sampling plans with modifications. Multi-level continuous sampling plans and sequential sampling plans. Distribution of effort in related sampling plans. Quality control with emphasis on recent developments. PREREQUI SITE: Ma 304B or Ma 322A.

Ma 401B ANALOG COMPUTERS (4-0). Elementary analog devices which may be used to perform addition, multiplication, vector resolution, function generation, integration, etc. Combinations of such devices for solution of differential equations, systems of linear equations, algebraic equations, harmonic analysis, etc. Gimbal solvers. Digital differential analyzers. PREREQUISITE: Ma 240C or equivalent.

Ma 402B ANALOG COMPUTERS (2-0). Theory of D.C. Amplifiers, servos, plotters and function multipliers. Analog solution to simultaneous differential equations of any order. Solution of the Legendre, Bessel and Hermite equations. PREREQUISITE: Ma 240C or equivalent.

Ma 411C DIGITAL COMPUTERS AND MILITARY APPLICATIONS (4-0). Description of a general purpose digital computer. Programming fundamentals. The use of subroutines, assembly routines and compilers in programming. Applications such as war gaming, simulation of systems, logistics and data processing, demonstrations on a computer. PREREQUISITE: Ma 073C or equivalent.

Ma 412C SMALL SCALE DIGITAL COMPUTERS (3-2). Octal and binary number systems. Description of general purpose digital computers. Operating characteristics and fundamentals of programming for the CDC-160A. Programming with meteorological applications, and operation of the 160. Course designed for meteorology students who may be expected to program for, and operate similar equipment upon completion of study. PREREQUISITE: Ma 381C.

Ma 416C NUMERICAL METHODS AND FORTRAN PROGRAMMING (4-1). Numerical solutions of systems of linear and nonlinear algebraic equations; finite differences; numerical interpolation, differentiation; integration; numerical methods of solving initial value and boundary value problems. The first half of course is devoted to learning the Fortran language and writing programs of increasing complexity. In the last half of the course attention is focused mainly on the numerical methods, making use of already existing library subroutines to supplement theory with examples. PREREQUISITE: Calculus, Differential Equations.

Ma 420E COMPUTER OPERATION (1-1). (For 5 wks.). This is a non-credit course designed for students whose course or thesis work requires a knowledge of computer operation. In a combination of lecture and laboratory periods details of operation of computer and peripheral equipment are covered as well as input-output techniques and power-on, power-off procedures. PREREQUISITE: Ma 412C or equivalent.

Ma 421C INTRODUCTION TO DIGITAL COMPUTERS (4-1). Octal and binary number systems. Description of general purpose digital computer. Operating characteristics and fundamentals of programming. Programming, using assembly routines and compilers. Engineering applications of digital computers. A *portion* of the laboratory period is devoted to operating the computers. PREREQUISITE: None.

Ma 423B ADVANCED DIGITAL COMPUTER PROGRAMMING (4-0). Theory and design of sub-routines, assembly routines and compilers. Symbol manipulation. Problem oriented languages and control languages. PREREQUISITE: Ma 421C.

Ma 426B ADVANCED NUMERICAL METHODS (4-1). Representations of functions and/or data by Chebyshev approximation, Continued Fractions, Economization of Series, Quadrature Methods and Multivariate Interpolation by least squares. Matrices and Linear Systems. Methods for Numerical Quadrature. Multiple Quadrature by Monte Carlo Methods. Numerical Solution of Differential Equations. PREREQUISITE: Ma 416C or equivalent.

Ma 427C PROGRAMMING I—INTRODUCTION (3-1). General description of data processing equipment from card/tape ancillary equipment to large-scale digital computer systems. History and development of computing devices. Characteristics of a digital computer and its operation. Programming in a problem-oriented language, e.g., FORTRAN, ALGOL, COBOL; the particular choice depending on the availability of the system for the School's computers and the special interests of the class. PREREQUISITE: None.

Ma 428B PROGRAMMING IIa (3-1). Binary and octal number systems. Programming in machine language for the CDC 1604. Use of USNPGS's SCRAP assembly routine. Problem solving and program planning techniques. Use of subroutines, program testing aids and monitor systems. Input/output considerations. Introduction to advanced topics such as parallel processing, time-sharing and satellite computers. PREREQUISITE: Ma 427C.

Ma 429A PROGRAMMING IIb (3-0). Evaluation of different computer systems—hardware and software. Critical review of available programming languages, machine- and problem-oriented. Systems programming. Theory and construction of assembly and compiler programs. Executive routines and monitor systems. Large scale programming efforts, e.g., NTDS and SAGE system. Multi-computer configurations. PREREQUISITE: Ma 428B.

Ma 501C THEORY OF NUMBERS (3-0). Divisihility, congruences, quadratic reciprocity, diophantine equations, continued fractions, partitions. PREREQUISITE: Consent of Instructor.

Ma 502B DIFFERENTIAL GEOMETRY (3-0). Curves and surfaces. Parametric representation. Curvature. Principal normal. Binomial. Torsion. The Frenet formula. Transformations of coordinates. Covariant and contravariant vectors. Symmetric and skew-symmetric tensors. Christoffel symbols. Reimannian tensor. Gaussian curvature Geodesics. PREREQUISITE: Consent of Instructor.

Ma 503B FOUNDATION OF MATHEMATICS (3-0). Fundamental concepts of mathematics with some emphasis on the axiomatic method including consistency, completeness and independence of axioms in an axiom system. PREREQUISITE: Consent of Instructor.

Ma 504C CALCULUS OF FINITE DIFFERENCES (3-0). Finite differences, factorial polynomials, sums, infinite products, Bernoulli numbers and polynomials, linear difference equations. PREREQUISITE: Consent of Instructor.

Ma 524A BOOLEAN ALGEBRA (3-0). A treatment of Boolean algebra as an abstract mathematical system. The interrelationships between Boolean algehra, set theory and logic are stressed through the algehra of sets and the statement calculus. Stone representation theorem for a Boolean algebra is covered in detail. PREREQUISITE: Ma 705B or equivalent.

Ma 541B APPLIED MATHEMATICS (3-0). Green's function techniques for solving Sturm-Liouville problems for ordinary differential equations as well as boundary and initial value problems for partial differential equations of mathematical physics are introduced. Operational calculus. PREREQUISITE: Consent of Instructor.

Ma 542B APPLIED MATHEMATICS (3-0). A continuation of Ma 541B. The material introduced in Ma 541B is studied more extensively. PREREQUISITE: Ma 541B.

Ma 546B SPECIAL FUNCTIONS (3-0). Special functions of mathematical physics. Orthogonal polynomials. Legendre functions. Bessel functions. Mathieu functions. Spherical harmonics. Recursion formulas, Rodrigues' formulas. Generating functions. Addition theorems. Relationship with hypergeometric differential equation. Expansion and orthogonality properties. PREREQUISITES: Consent of Instructor.

Ma 548B PARTIAL DIFFERENTIAL EQUATIONS (3-0). The Cauchy problem for partial differential operators. Cauchy-Kowalewsky Theorems. Methods of characteristics. Well-posed problems for elliptic, hyperbolic and parabolic partial differential equations. PREREQUISITE: Consent of Instructor.

Ma 549B FOURIER BESSEL EXPANSIONS AND CALCULUS OF VARIATIONS (2-0). Partial differential equations, separation of variables. Sturm-Liouville systems, Fourier Bessel expansions, orthogonal functions, Bessel's inequality. Euler equations, Hamilton's principle, application to physics. PREREQUISITE: Consent of Instructor.

Ma 555A INTEGRAL EQUATIONS (3-0). Fredholm integral equations of the first and second kinds. The Fredholm alternative. Volterra equations. Neumann series. Integral equations with symmetric kernels. Hilbert-Schmidt theory. Singular equations. Applications. PREREQUISITE: Consent of Instructor.

Ma 571B THEORY OF FUNCTIONS OF A COMPLEX VARIABLE (3-0). Selected topics from the theory of functions of a real variable. Complex functions and analytic functions. Integration in the complex plane. Series of complex functions. Power series. Laurent series. PREREQUISITE: Consent of Instructor.

Ma 572B THEORY OF FUNCTIONS OF A COMPLEX VARIABLE (3-0). Singularities of complex functions. Residues and contour integration. Zeros of analytic functions, factors of and infinite product representations for analytic functions. Maximum modulus theorems for analytic and harmonic functions. Conformal mapping. PREREQUISITE: Ma 571B or consent of Instructor.

Ma 573A THEORY OF FUNCTIONS OF A COMPLEX VARIABLE (3-0). Special functions of a complex variable. Analytic theory of differential equations. PREREQUISITE: Ma 572B or consent of Instructor.

Ma 576A LAPLACE TRANSFORMATIONS (3-0). Theory of the Laplace transform with particular reference to its properties as a function of a complex variable. Applications of the transform to difference, differential, integral equations of convolution type and houndary value problems. Sturm-Liouville systems. PREREQUISITE: Ma 573A or consent of Instructor.

Ma 701B SEMINAR IN ANALYSIS (2-0). Topics in analysis. Content of the course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of Instructor.

Ma 705B SET THEORY (3-0). Elementary logic and methods of proof in mathematics; properties of sets and operations with sets; relations and functions from a set-theoretic point of view; equivalence of sets and their cardinality; infinite sets and their classification by cardinal numbers. PREREQUISITE: Differential and integral calculus or consent of Instructor.

Ma 709A FUNCTIONS OF REAL VARIABLES (3-0). Review of set theory and real numbers. Topological and metric spaces, convergence of directed functions, continuity and semicontinuity. Functions of bounded variation, absolutely continuous functions, differentials. PREREQUISITE: Ma 109B.

Ma 710A FUNCTIONS OF REAL VARIABLES (3-0). Continuation of Ma 709. Lebesque-Stieltjes integrals, meas-

ure and measurable function. Radon-Nikodym theorem, function spaces, L*p* spaces. PREREQUISITE: Ma 709A.

Ma 711A INTRODUCTION TO FUNCTIONAL ANALYSIS (3-0). Linear spaces and functionals. Banach and Hilbert spaces. Weak and weak* topologies, completely continuous operators, spectral theorems. PREREQUISITE: Consent of Instructor.

Ma 740A CALCULUS OF VARIATIONS (3-0). Bliss's differential methods, adjoint differential equations. Euler equations, maximum principle. Weirstrass and Legendic conditions. Perturbation techniques, numerical procedures for determining solutions, and application to control problems. PREREQUISITES: Ma 240C or the equivalent and Ma 412C or consent of Instructor.

Ma 751B TENSOR ANALYSIS I(3-0). The basic concepts of differential geometry. Definition of a tensor. Physical interpretations. The metric tensor. Covariant differentiation. Geodesics. PREREQUISITES: Ma 120C, Ma 181D, Ma 182C or the equivalent.

Ma 752A TENSOR ANALYSIS II (3-0). A continuation of Ma 751B. Introduction to special relativity theory, with emphasis upon axiomatic and philosophical foundations. Formulation of the laws of mechanics and electromagnetism in relativistic form. PREREQUISITE: Ma 751B and a sound background in classical mechanics and electromagnetism.

Ma 753A TENSOR ANALYSIS III (3-0). A continuation of Ma 752A. Introduction to general relativity theory. Parallel displacement and the curvature tensor. PREREQUISITE: Ma 752A.

Ma 801A SEMINAR IN ANALYSIS. Subject matter of this seminar will in general be left to the discretion of instructors; usually content will be special topics from the fields of functional analysis and partial differential equations. Number of hours subject to arrangement. PREREQUISITE: Consent of Instructor.

Ma 831B SEMINAR IN PROBABILITY AND STATISTICS. Content of the course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of Instructor.

Ma 832A SEMINAR IN PROBABILITY AND STATISTICS. Content of the course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of Instructor.

Ma 842A DATA PROCESSING SEMINAR (3-0). A working seminar on advanced topics in information processing. The selection of topics will depend on the instructor and the class interest. PREREQUISITE: Consent of Instructor.

Ma 931B READING IN PROBABILITY AND STATISTICS. Content of the course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of Instructor.

Ma 932B READING IN PROBABILITY AND STATISTICS. Content of the course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of Instructor.

MECHANICS

Mc 101D ENGINEERING MECHANICS I (2-2). Review of statics, free-body diagrams; distributed forces; centroids; moments and products of inertia of areas; hydrostatics; friction, general principles of dynamics; dimensional analysis; kinematics of a particle; relative and absolute time rate of change of a vector; Coriolis acceleration. PREREQUISITES: Ma 120C or Ma 150C (may be taken concurrently).

Mc 102D ENGINEERING MECHANICS II (2-2). Dynamics of a particle; impulse and momentum; work and energy; potential; conservation of energy; vibrating systems, free and forced, with and without damping; impact; dynamics of rigid bodies; moments and products of inertia; principal axes of inertia; the gyroscope. PREREQUISITE: Mc 101D.

Mc 111C VECTOR MECHANICS I (4-0). Review of vector algebra and statics. Reduction of a general force system and Poinsot's central axis. Axial and polar vectors. Centroids. Vector kinematics referred to a rotating coordinate frame. The Coriolis theorem and its application to curvilinear coordinates. Potential energy and stability. Particle dynamics. Spherical pendulum. PREREQUISITE: A previous course in mechanics.

Mc 112C VECTOR MECHANICS II (4-0). Vector dynamics of rigid bodies. The instantaneous screw axis. Euler angles. Body and space centrodes. Ellipsoid of inertia and principal axes. Poinsot's force free motion and the forced precession of a gyro, with application to the earth. Dynamical stability of a gyro by complex variable. Elementary theory of missile stability. PREREQUISITE: Mc 111C.

Mc 201B METHODS IN DYNAMICS (2-2). The principles of linear momentum, angular momentum, work and energy, power and energy, conservation of energy, virtual work, and d'Alembert are developed and discussed in detail. This work is followed by a development and interpretation of Lagrange's equations of motion. Application of these various principles to obtain the differential equations of motion of dynamical systems is given particular attention. PREREQUISITE: Mc 102D.

Mc 311C VIBRATIONS (3-2). Kinematics of vibrations; free and forced vibrations of systems with one degree of freedom; theory of vibration measuring instruments and of vibration insulation; systems with many degrees of freedom; normal modes of vibration; computation of fastest and slowest modes by matrix methods; vibrations of strings; beams, shafts and membranes. Rayleigh's method; Stodola's

method; critical speeds; self-excited vibrations; effects of impact on elastic structures. PREREQUISITES: Mc 102D and a course in beam deflection theory.

Mc 402B MECHANICS OF GYROSCOPIC INSTRUMENTS (3-0). Review of the vector kinematics and dynamics involved in the angular motion of rigid bodies; steady, free and forced precession and general motion of a gyro; stability of a free gyro; the gyrocompass and gyropendulum; gyro angular velocity indicator; the stable platform; Shuler tuning of inertial guidance instruments. PREREQUISITE: Mc 102D.

Mc 403B KINEMATICS OF GUIDANCE (3-0). Kinematics and geometry of guidance and interception systems; special coordinates; inertial reference frames; accelerometers; inertial guidance; Dovap; guidance of a ballistic missile and of an interceptor; perturbations and the adjoint differential equations in guidance and optimum control; introductory orbit theory. PREREQUISITE: A course in differential equations and Mc 102D.

Mc 404B MISSILE MECHANICS (3-0). A survey of ballistic missile dynamics including discussions of atmospheric structures; standard conditions; drag; stability derivatives; equations of yawing, swerving and angular motion; electronic digital integration of equations of motion; effects of variations from standard conditions; rocket motor thrust and torque; tricyclic motion; aeroballistic range measurements of stability derivatives; contributions of aerodynamic jump and drift to dispersion; dynamic wind tunnel tests; dynamic stability. PREREQUISITE: A course in dynamics.

Mc 405B ORBITAL MECHANICS (3-0). Review of kinematics. Lagrange's equation of motion. The earth's gravitational field. Control force motion. The two body problem. The determination of orbits. The three body problem. Perturbations. PREREQUISITE: Mc 102D.

Mc 406A INTRODUCTORY CONTROL AND GUIDANCE (4-0). Elements of orbits, orbit determination, gravitational harmonics due to oblateness. Equation of motion of a rocket; integration for thrust constant. Variational and adjoint equations in trajectory determination and optimization; perturbations. Rendezvous and interception trajectories, impulse solutions, error correction. Closed form solutions for nearly circular orbits. Pitch, yaw, roll stabilization. Stable platform. Intertial guidance of airplanes and missiles. PREREQUISITE: Ph 153A.

DEPARTMENT OF MECHANICAL ENGINEERING

Robert Eugene Newton, Professor of Mechanical Engineering; Chairman (1951)*; B.S. in M.E., Washington Univ., 1938; M.S., 1939; Ph.D., Univ. of Michigan, 1951.

Dennis Kavanaugh, Professor Emeritus of Mechanical Engineering (1926); B.S., Lehigh Univ., 1914.

John Edison Brock, Professor of Mechanical Engineering (1954); B.S.M.E., Purdue Univ., 1938; M.S.E., 1941; Ph.D., Univ. of Minnesota, 1950.

Gilles Cantin, Associate Professor of Mechanical Engineering (1960); B.A.Sc., Ecole Polytechnique (Montreal), 1950; M.Sc., Stanford Univ., 1960.

Virgil Moring Faires, Professor of Mechanical Engineering (1958); B.S. in M.E., Univ. of Colorado, 1922; M.S., 1925; M.E., 1926.

Ernest Kenneth Gatcombe, Professor of Mechanical Engineering (1946); B.S., Univ. of Maine, 1931; M.S., Purdue Univ., 1939; Ph.D., Cornell Univ., 1944.

Cecil Dudley Gregg King, Associate Professor of Mechanical Engineering (1952); B.E., Yale Univ., 1943; M.S. in M.E., Univ. of California (Berkeley), 1952.

Paul James Marto, Lieutenant Junior Grade, U.S. Naval Reserve; Assistant Professor of Mechanical Engineering (1965); B.S., Univ. of Notre Dame, 1960; M.S. in Nuc. Sci., Massachusetts Institute of Technology, 1962; Sc.D., 1965.

Roy Walters Prowell, Professor of Mechanical Engineering (1946); B.S. in I.E., Lehigh Univ., 1936; M.S. in M.E., Univ. of Pittsburgh, 1943.

Paul Francis Pucci, Associate Professor of Mechanical Engineering (1956); B.S. in M.E., Purdue Univ., 1949; M.S. in M.E., 1950; Ph.D., Stanford Univ. 1955.

Harold Marshall Wright, Professor of Mechanical Engineering (1945); B.Sc. in M.E., North Carolina State College, 1930; M.M.E., Rensselaer Polytechnic Institute, 1931.

*The year of joining the Postgraduate School faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN MECHANICAL ENGINEERING

Following is a statement of departmental minimum requirements for degrees in Mechanical Engineering. It is noted that candidates for these degrees must also satisfy general degree requirements as determined by the Academic Council.

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

a. Entrance Requirements. Prior to entering an approved curriculum, a student must have successfully completed college courses as follows: Mathematics through integral calculus, one year of chemistry, and one year of physics. In addition, through completed course work or examination, the student must demonstrate a knowledge of the fundamentals of engineering graphics.

b. Mechanical Engineering Courses. Minimum credit of 65 term hours in mechanical engineering courses is required. These must include the following minimum number of term hours in the indicated areas. The minimum acceptable quality point ratio in these courses is 1.0.

Area	*Minimum Term Hours*
Energy Conversion (Includes thermodynamics, gas dynamics, heat transfer, internal combustion engines. Must include a course in power plants.)	18
Applied Mechanics (Includes statics, dynamics, fluid mechanics, and vibrations.)	15
Mechanics of Solids and Machine Design (Includes kinematics of machinery. Must include a course in machine design.)	15

c. Other Specific Coverage. The following minimum requirements must be met in each of the indicated disciplines.

MATHEMATICS—One course in each of the following subjects: vector algebra, differential equations, and digital computers.

ELECTRICAL ENGINEERING—15 term hours.

METALLURGY—6 term hours.

Some of these requirements may, with the consent of the department, be met by transfer credit.

d. Upper Division Credit. Minimum credit of 105 term hours in upper division or higher level courses is required.

e. Department Approval. Any program leading to award of this degree must be approved by the department at least 3 terms before completion. In general, approved programs will require more than the minimum degree requirements in order to conform to the needs and objectives of the U.S. Navy.

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

a. Undergraduate Preparation. A candidate shall have satisfied the requirements for the degree Bachelor of Science in Mechanical Engineering. Credit requirements in succeeding paragraphs must be met by courses in addition to those used to satisfy this requirement.

b. Mechanical Engineering Courses. Minimum credit of 20 term hours in A level courses in mechanical engineering is required.

c. Courses in Other Departments. A minimum of 12 term hours of graduate credit must be earned outside the major department.

d. A Level Courses. At least 24 term hours of A level courses must be included in the program. Courses used to meet the requirement of paragraph b may also be counted to meet this requirement.

e. Thesis. Completion of a thesis and its acceptance by the department are required. For this a maximum of 8 term hours of graduate credit may be allowed toward satisfaction of the school requirement for 48 term hours. The thesis credit may not be used to satisfy any of the requirements of paragraphs b and d.

f. Department Approval. Any program leading to award of this degree must be approved by the department at least 3 terms before completion. In general, approved programs will require more than the minimum degree requirements in order to conform to the needs and objectives of the U.S. Navy.

MECHANICAL ENGINEERING

ME 061D MECHANICS I (4-0). Forces and force systems, moments and couples, resultants, equilibrants, free body diagrams, equilibrium of a free body, simple structures, friction, first and second moments, centroids, basic concepts of kinematics. TEXT: Fairman and Cutshall, *Engineering Mechanics.* PREREQUISITE: Ma 052D.

ME 062D MECHANICS II (4-0). Newton's laws, d'Alembert's principle, work and energy, impulse and momentum, rocket motion, Kepler's laws, artificial satellites and space vehicles. TEXT: Fairman and Cutshall, *Engineering Mechanics.* PREREQUISITES: Ma 053D and ME 061D.

ME 111C ENGINEERING THERMODYNAMICS I (5-0). The laws and processes of transforming energy from one form to another; first law analysis; second law analysis and cycle analysis for reversible processes; transient flow; irreversible processes and available energy. Applications to ideal gas cases; internal combustion engines, gas turbines, turbojets, rockets. TEXT: Faires, *Thermodynamics.* PREREQUISITE: Ma 230D.

ME 112C ENGINEERING THERMODYNAMICS II (5-0). Continuation of ME 111C. Applications of thermodynamic principles to marine steam power plants; reversed cycles; gas-vapor mixtures; combustion with dissociation problems; general methods of handling imperfect gas problems. TEXT: Faires, *Thermodynamics.* PREREQUISITE: ME 111C.

ME 132C ENGINEERING THERMODYNAMICS II (4-2). Continuation of ME 111C. Applications of thermodynamic principles to marine power plant equipment, steam power plants and cycles, refrigeration and heat-pump systems, gas-vapor mixtures. Methods of handling imperfect gases. Complementary laboratory experiments. TEXT: Faires, *Thermodynamics.* PREREQUISITE: ME 111C.

ME 142C THERMODYNAMICS (4-0). Survey of engineering thermodynamics with emphasis on the application of thermodynamic principles to marine nuclear power plants. Review of first and second laws of thermodynamics, and properties of two phase fluids. Power plant cycles. Steam turbines. Elementary fluid mechanics and heat transfer. TEXT: Faires, *Thermodynamics.* PREREQUISITE: PH 530C.

ME 210C APPLIED THERMODYNAMICS (3-2). Continuation of the application of thermodynamic principles, fluid mechanics and the thermodynamics of compressible flow, turbine blading, elements of heat transfer. Complementary laboratory experiments. PREREQUISITE: ME 132C.

ME 211B THERMODYNAMICS OF COMPRESSIBLE FLOW (3-0). The thermodynamic and dynamic fundamentals of compressible fluid flow. One-dimensional analyses including the effects of area change, friction, and heat transfer. TEXT: Shapiro, *Thermodynamics and Dynamics of Compressible Fluid Flow, Vol. 1.* PREREQUISITES: ME 112C, ME 411C, and Ma 113B.

ME 212A ADVANCED THERMODYNAMICS (3-0). Mathematical development of property relations and their use with experimental data; energy conversion systems employing thermoelectricity, thermionics, MHD, photovoltaic effect, and fuel cells. TEXTS: Faires, *Thermodynamics;* Chang, *Energy Conversion.* PREREQUISITES: ME 112C and Ma 113B.

ME 217B INTERNAL COMBUSTION ENGINES (3-2). Theoretical and real-fuel cycles, combustion processes for spark-ignition and compression-ignition engines. Combustion chambers, carburetion and fuel-injection phenomena. Factors affecting engine performance and design. TEXT: Taylor and Taylor, *Internal Combustion Engines.* PREREQUISITE: ME 112C.

ME 221C GASDYNAMICS AND HEAT TRANSFER (4-2). Fundamentals of one-dimensional compressible fluid flow including effects of area change, friction, and heat addition. Fundamentals of conduction, convection, and radiation heat transfer, including heat exchanger analysis. TEXT: Giedt, *Principles of Engineering Heat Transfer.* PREREQUISITES: ME 112C and ME 411C.

ME 222C THERMODYNAMICS LABORATORY (1-4). Laboratory experiments applying thermodynamic principles to a gas turbine engine, refrigeration plant, air compressor, compressible flow metering and heat transfer. TEXT: Faires, *Thermodynamics.* PREREQUISITES: ME 112C and ME 411C.

ME 223B MARINE POWER PLANT ANALYSIS (2-4). Preliminary planning of marine power plants. Estimation of hull, main engine and auxiliary power requirements, interrelationship of components, heat balances and flow diagrams, computation of ship and plant performance indices, preliminary investigation of major equipment items. PREREQUISITE: ME 221C or equivalent.

ME 230B MARINE POWER PLANT ANALYSIS (2-4). Preliminary planning of ship propulsion plants. Estimation of hull, main engine and auxiliary power requirements, interrelationship of components, heat balances, computa-

tion of ship and plant performance indices, preliminary investigation of some major equipment items. PREREQUISITE: ME 211B or equivalent.

ME 240B NUCLEAR POWER PLANTS (4-0). Survey of nuclear power engineering. The reactor as a power source as affected by technical feasibility and economics. Elementary nuclear reactor physics. Engineering considerations in core design, including problems of core design, power removal and utilization and shielding. Discussion of reactor types. TEXT: King, *Nuclear Power Systems.* PREREQUISITES: ME 210C or ME 221C; PH 621B.

ME 241A NUCLEAR PROPULSION SYSTEMS I (4-0). The first of a two-course sequence covering engineering aspects of nuclear power reactors. Reactor types, characteristics, and criteria for selection. Advanced heat transfer, fluid mechanics and thermodynamics as applied to characteristic cycles. TEXT: Glasstone, *Principles of Nuclear Reactor Engineering.* PREREQUISITES: ME 310B and PH 652A.

ME 242A NUCLEAR PROPULSION SYSTEMS II (3-3). Reactor shielding. Elementary thermal core and plant design. Detailed study of existing reactor plants. TEXT: Glasstone, *Principles of Nuclear Reactor Engineering.* PREREQUISITE: ME 241A.

ME 310B HEAT TRANSFER (4-2). The fundamentals of heat transfer mechanisms; one and two dimensional conduction, free and forced convection, condensation, boiling, thermal radiation, transient and periodic systems, and heat exchanger analysis. Use of the thermal circuit, analog, numerical and graphical techniques. TEXT: Kreith, *Principles of Heat Transfer.* PREREQUISITES: ME 112C, ME 412A, and Ma 113B.

ME 411C MECHANICS OF FLUIDS (4-2). Mechanical properties of fluids, hydrostatics, buoyancy and stability analysis. Energy aspects of ideal and real fluid flow, flow metering and control. Impulse-momentum principles and analysis. Dimensional analysis and similitude. Elements of hydrodynamic lubrication. Analysis of fluid machinery and fluid systems. Laboratory experiments and problem work. TEXT: Streeter, *Fluid Mechanics.* PREREQUISITES: Ma 230D and ME 502C.

ME 412A ADVANCED MECHANICS OF FLUIDS (4-2). Potential flow theory. Linearized compressible flow. Oblique shock relations. Viscous flow and boundary layer theory. TEXTS: Shapiro, *Thermodynamics and Dynamics of Compressible Flow, Vols. I and II.* PREREQUISITES: ME 411C, Ma 113B.

ME 501C MECHANICS I (4-0). Laws of statics. Force systems, equilibrium, simple structures, distributed forces, friction, virtual work. Basic concepts of kinematics. TEXT: Beer and Johnston, *Vector Mechanics.* PREREQUISITE: Ma 120C (may be concurrent).

ME 502C MECHANICS II (4-0). Kinematics, Newton's laws, kinetics of particles. Work and energy, impulse and momentum. Moment of inertia of mass. Kinetics of rigid bodies. TEXT: Beer and Johnston, *Vector Mechanics.* PREREQUISITE: ME 501C and Ma 240C (may be taken concurrent).

ME 503A ADVANCED MECHANICS (4-0). Intensive treatment of vector kinematics. Orbital mechanics including major perturbations for earth satellites. The inertia tensor (dyadic). Rigid body kinetics. Jacobian elliptic functions. Lagrangian methods. TEXTS: Yeh and Abrams, *Mechanics of Solids. Vol. I;* Synge and Griffith, *Principles of Mechanics.* PREREQUISITE: ME 502C.

ME 504B ADVANCED DYNAMICS (4-0). Restatement of laws of mechanics. Particle kinetics in different coordinate systems. Effects of earth's rotation. Tensor of inertia. General motion of a rigid body. Gyroscopes. Numerical procedures. Generalized coordinates and Lagrange's equations. TEXTS: Yeh and Abrams, *Mechanics of Solids. Vol. I;* Timoshenko and Young, *Advanced Dynamics.* PREREQUISITE: ME 502C.

ME 510C MECHANICS OF SOLIDS I (4-2). Stress, strain, Hooke's law, tension and compression, shearing stresses, connections, thin vessels, torsion, statics of beams, stresses in beams, deflections of beams, combined loadings and combined stresses, columns. Strain energy, impact, simple indeterminate structures. Supporting laboratory work. TEXT: Timoshenko and Young, *Elements of Strength of Materials.* PREREQUISITES: Ma 230D and ME 501C.

ME 511A MECHANICS OF SOLIDS II (5-0). Further elastic analysis of statically indeterminate structures, beam columns, curved beams, unsymmetrical bending, shear center, beams on elastic foundations, plates and shells, thick-walled cylinders, rotating discs, and elementary thermal stresses. TEXTS: Timoshenko,*Strength of Materials. Vols. I and II.* PREREQUISITES: ME 510C and Ma 240C.

ME 512A MECHANICS OF SOLIDS III (4-0). Elements of theory of elasticity. Stress tensor and theories of failure. Torsion of non-circular sections. Plastic analysis. Matrix methods in structural analysis. Brittle fracture. TEXTS: Timoshenko, *Strength of Materials, Vol. I;* Timoshenko and Goodier, *Theory of Elasticity;* Parker, *Brittle Behavior of Engineering Structures.* PREREQUISITES: Ma 113B and ME 511A.

ME 521C MECHANICS OF SOLIDS II (4-0). Statically indeterminate problems in bending, symmetrical beams of variable cross section, beams of two materials, unsymmetrical bending, thick-walled cylinders, rotating disks, curved bars, beams with combined axial and lateral loads. TEXTS: Timoshenko, *Strength of Materials, Vols. I and II.* PREREQUISITES: ME 510C and Ma 240C.

ME 522B MECHANICS OF SOLIDS III (4-0). Stress concentration, deformations beyond the elastic limit, mechanical properties of materials, strength theories, impact, fatigue, torsion of non-circular sections, thin plates and shells. TEXT: Timoshenko, *Strength of Materials, Vol. II.* PREREQUISITE: ME 521C.

ME 540C MECHANICS OF SOLIDS (3-2). Fundamental concepts of the mechanics of solids. Stress, strain, Hooke's law, tension, compression, shearing stresses, bending stresses, beam deflections, combined stresses, columns. Laboratory experiments based on standard mechanical tests. TEXT: Timoshenko and Young, *Elements of Strength of Materials.* PREREQUISITES: Ma 240C, PH 151C.

ME 547C STATICS AND STRENGTH OF MATERIALS (5-0). Review of principles of statics, statics of determinate structures, pin-connected trusses. Stress, strain, Hooke's law, tension and compression, shearing stresses. Connections, thin vessels, torsion. Statics of beams, flexural stresses and deformations, numerical procedures. Simple indeterminate structures. Combined loadings and combined stresses. Columns. TEXT: Timoshenko and Young, *Elements of Strength of Materials.* PREREQUISITE: PH 151C.

ME 548B STRUCTURAL THEORY (5-0). Fundamental concepts. Stability and determinacy of simple trusses and frames. Space frames. Hyperstatic structures. Energy methods. Slope deflection and moment distribution. Dynamic disturbance. Systems with one, two and many degrees of freedom. TEXTS: McCormac, *Structural Analysis;* Rogers, *Dynamics of Framed Structures.* PREREQUISITES: ME 547C and Ma 240C.

ME 561C MECHANICS I (4-0). Forces and force systems, moments and couples, resultants, equilibrants, free body diagrams, equilibrium of a free body, simple structures, friction, first and second moments, centroids, basic concepts of kinematics. TEXT: Meriam, *Mechanics.* PREREQUISITE: Ma 052D.

ME 562C MECHANICS II (4-0). Newton's laws, d'Alembert's principle, work and energy, impulse and momentum, rocket motion, Kepler's laws, artificial satellites and space vehicles. TEXT: Meriam, *Mechanics.* PREREQUISITES: ME 561C and Ma 053D.

ME 612A EXPERIMENTAL MECHANICS (3-2). Fundamentals of mechanical measurements, resistance strain gages, transducers and instrumentation systems, dynamic response characteristics, brittle lacquer, photoelasticity, analog methods, model theory. Complementary laboratory experiments. TEXTS: Beckwith and Buck, *Mechanical Measurements;* Perry and Lissner, *Strain Gage Primer;* Lee, *An Introduction to Experimental Stress Analysis.* PREREQUISITES: ME 512A and ME 712A.

ME 622B EXPERIMENTAL MECHANICS (2-2). Fundamentals of mechanical measurements, resistance strain gages, transducers and instrumentation systems, dynamic response characteristics, photoelasticity. Complementary laboratory experiments. TEXTS: Lee, *An Introduction to Experimental Stress Analysis;* Perry and Lissner, *Strain Gage Primer.* PREREQUISITES: ME 522B and ME 722B.

ME 711B MECHANICS OF MACHINERY (3-2). Algebraic analysis of the motion of cam followers; design of cams. Velocities and acceleration of machine parts. Kinematics of gearing. Synthesis. Dynamic forces on machine members. TEXT: Faires, *Kinematics.* PREREQUISITE: ME 502C.

ME 712A THEORY OF VIBRATIONS (3-2). The single degree of freedom linear system. Multidegree linear systems. Emphasis is on matrix treatments, including the complex eigenvalue problem and approximations valid for small damping. Transfer matrix methods. Introduction to nonlinear systems. Laboratory experiments to illustrate principles and introduce use of analog computer. TEXTS: Duplicated notes and Den Hartog, *Mechanical Vibrations.* PREREQUISITES: Ma 280B and ME 511A.

ME 713A ADVANCED DYNAMICS OF MACHINERY (3-0). Special topics such as: shock and vibration mounts, torsional vibrations of crank shafts, vibration absorbers, special bearings, gear lubrication, sleeve bearings with pulsating loads, oil film whirl, turbine blade vibrations, nonlinear vibration problems. Additional matrix methods. TEXTS: Den Hartog, *Mechanical Vibrations;* Karman and Biot, *Mathematical Methods in Engineering.* PREREQUISITE: ME 712A.

ME 722B MECHANICAL VIBRATIONS (3-2). Free and forced vibration of linear systems having one, two, and many degrees of freedom. Matrix methods. Vibration isolation and absorbers, torsional vibration, continuous systems. Laboratory experiments with prototype and simulated systems. TEXTS: Den Hartog, *Mechanical Vibrations;* Thomson, *Mechanical Vibrations.* PREREQUISITES: Ma 113B and ME 521C.

ME 811B MACHINE DESIGN I (3-2). First of a two-course sequence. Studies of fits, tolerances, allowances, material selection, stress concentration, bearings, shafting, screws, belts, chains, brakes, clutches and cams. TEXT: Faires, *Design of Machine Elements.* PREREQUISITES: ME 512A and ME 711B.

ME 812B MACHINE DESIGN II (3-4). Continuation of ME 811B; springs, gearing, and advanced design problems. Machine design projects of a comprehensive nature. TEXT: Faires, *Design of Machine Elements.* PREREQUISITES: ME 811B and ME 712A.

ME 820C MACHINE DESIGN (2-4). Studies of fits, tolerances, allowances, stress concentration, material selection, bearings, gears, shafts, cams, springs, screws, brakes and clutches. TEXT: Faires, *Design of Machine Elements.* PREREQUISITES: ME 522B and ME 711B.

ME 900A ADVANCED TOPICS IN MECHANICAL ENGINEERING (4-0). Investigation of selected advanced Mechanical Engineering topics. PREREQUISITE: Department approval.

ME 910E NAVAL ARCHITECTURE SEMINAR (3-0). Seminar discussions of various phases of naval architecture. Typical discussion subjects will be: drydocking, launching procedures and calculations, elements of ship resistance, action of ship propulsion devices, hull efficiencies and some aspects of small craft design. PREREQUISITE: ME 223B or ME 230B.

Experimental stress study in mechanical engineering.

DEPARTMENT OF METEOROLOGY AND OCEANOGRAPHY

GEORGE JOSEPH HALTLINER, Chairman, Professor of Meteorology (1946)*; B.S., College of St. Thomas, 1940; Ph.M., Univ. of Wisconsin, 1942; Ph.D., 1948.

HUGH WALLICK ALBERS, Lieutenant Commander, U.S. Navy; Instructor in Meteorology; B.S., USNA, 1949; B.S., USNPGS, 1955.

HAROLD LLEWELLYN BIXBY, Lieutenant Commander, U.S. Navy; Instructor in Meteorology; B.S., USNA, 1952; M.S., USNPGS, 1962.

BURFORD ARLEN CARLSON, Lieutenant Commander, U.S. Navy; Instructor in Meteorology; M.S., USNPGS, 1960.

WARREN WILSON DENNER, Assistant Professor of Oceanography (1964); B.S., Portland State College, 1961; M.S., Oregon State Univ., 1963.

WILLIAM DWIGHT DUTHIE, Professor of Meteorology (1945); B.A., Univ. of Washington, 1935; M.S., 1937; Ph.D., Princeton Univ., 1940.

GLENN HAROLD JUNG, Professor of Oceanography (1958); B.S., Massachusetts Institute of Technology, 1949; M.S., 1952; Ph.D., Texas Agricultural and Mechanical College, 1955.

THOMAS ALBERT LE DEW, Lieutenant Commander, U.S. Navy; Instructor in Meteorology; B.S., USNA, 1950; M.S., USNPGS, 1960.

FRANK LIONEL MARTIN, Professor of Meteorology (1947); B.A., Univ. of British Columbia, 1936; M.A., 1938; Ph.D., Univ. of Chicago, 1941.

VICTOR THOMAS NEAL, Assistant Professor of Oceanography (1964); B.S., Univ. of Notre Dame, 1948; M.S., Univ. of North Dakota, 1954.

JOHN HOOD POWELL, Lieutenant, U.S. Navy; Instructor in Meteorology; B.S., USNA, 1955; M.S., USNPGS, 1957.

ROBERT JOSEPH RENARD, Associate Professor of Meteorology (1952); M.S., Univ. of Chicago, 1952.

NORMAN MARSHALL STEVENSON, Lieutenant Commander, U.S. Navy; Instructor in Meteorology; M.S., USNPGS, 1960.

CHARLES LUTHER TAYLOR, Associate Professor of Meteorology (1954); B.S., Pennsylvania State Univ., 1942; M.S., 1947.

WARREN CHARLES THOMPSON, Professor of Oceanography (1953); B.A., Univ. of Calif., at Los Angeles, 1943; M.S., Scripps Institution of Oceanography, 1948; Ph.D., Texas Agricultural and Mechanical College, 1953. (Leave of absence.)

WILLEM VAN BIJL, Associate Professor of Meteorology (1961); B.Sc., Free Univ. of Amsterdam, 1941; M.Sc., 1943; Ph.D., State Univ. Utrecht, 1952.

JACOB BERTRAM WICKHAM, Associate Professor of Oceanography (1951); B.S., Univ. of California, 1947; M.S., Scripps Institution of Oceanography, 1949.

*The year of joining the Postgraduate School Faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN METEOROLOGY AND OCEANOGRAPHY

BACHELOR OF SCIENCE

Subject	*Term Hours Required*	
	B.S. in Meteorology	B.S. in Environmental Science
I Meteorology		
a. Descriptive	6	3
b. Dynamic	8	12
c. Physical	13	
d. Synoptic	22	20
II Oceanography		
a. Descriptive	6	6
b. Dynamic		12
c. Field and Lab		16
III Electives	20	31
	75	100

Electives may be chosen from any of I or II plus mathematics courses covering the following subjects: Probability and Statistics, Vector Analysis, Digital Computation, and Differential Equations. A research paper is required.

MASTER OF SCIENCE

Subject	*Term Hours Required*	
	M.S. in Meteorology	M.S. in Physical Oceanography
I Meteorology		
a. Dynamic	15	
b. Physical	11	
c. Synoptic	7	
II Oceanography		
a. Descriptive		12
b. Physical		20
c. Field and Lab		6
III Electives	29	18
	62	56

Electives may be chosen from any of I or II plus mathematics courses covering the following subjects: Probability and Statistics, Vector Analysis, Digital Computation, and Partial Differential Equations. At least 20 term hours must be A level Meteorology and Oceanography courses with the remainder not less than B level. An acceptable thesis is required. B.S. in Meteorology or equivalent is prerequisite to M.S. in Meteorology.

METEOROLOGY

Mr 001D WEATHER CODES AND ELEMENTARY ANALYSIS (0-3). Designed to acquaint Environmental Science students with weather codes and observation, stressing utility and application and to introduce the essential elements of meteorological analysis. TEXTS: WBAN Manual for Synoptic Codes; WBAN Manual for Radiosonde Code; WBAN Manual for Upper Wind Code; International Cloud Atlas. PREREQUISITE: None.

Mr 010D METEOROLOGY (3-0). The principles of meteorology and the effects of weather phenomena on naval operations. Included topics: structure of the atmosphere; weather elements; the station model, pressure and winds; theory of air masses and fronts; tropical storms; sources of weather information; sea and swell conditions; climatology and the principles of weather map analysis and forecasting. TEXT: Donn, *Meteorology with Marine Applications*. PREREQUISITE: None.

Mr 100D ELEMENTARY METEOROLOGY (3-0). Primarily designed to give non-meteorological officer students a survey of meteorology. Topics included are essentially the same as in Mr 200C; however, there is greater emphasis on large-scale and small-scale circulations. TEXT: Petterssen, *Introduction to Meteorology*. PREREQUISITE: None.

Mr 200C INTRODUCTION TO METEOROLOGY (3-0). A general course which treats descriptively the composition and vertical structure of the atmosphere, physical processes, general circulation, air masses, fronts, cyclones and anticyclones. TEXT: Same as Mr 100D. PREREQUISITE: None.

Mr 201C ELEMENTARY WEATHER-MAP ANALYSIS (0-9). Laboratory course taught in conjunction with Mr 211C. Practice in upper-air and surface analysis stressing basic techniques and continuity. TEXT: Same as Mr 211C. PREREQUISITES: Mr 200C and a knowledge of weather codes and observations.

Mr 202C WEATHER-MAP ANALYSIS (0-6). Laboratory course taught in conjunction with Mr 212C. Practice in sea-level and frontal analysis, graphical arithmetic, analysis of upper-air soundings, and vertical space/time cross sections. Introduces local forecasting techniques and mesoscale synoptic analysis. TEXT: Same as Mr 212C. PREREQUISITE: Mr 201C.

Mr 203C FORECASTING WEATHER ELEMENTS AND MESOMETEOROLOGY (0-6). Laboratory course taught in conjunction with Mr 213C. Practice in objectives and quantitative forecasting techniques and mesascale synoptic analysis. TEXT: Same as Mr 213C. PREREQUISITE: Mr 202C.

Mr 204B UPPER-AIR AND SURFACE PROGNOSIS (0-6). Laboratory course taught in conjunction with Mr 214B. Practice in prognosis of upper-air and surface charts using current and classical methods. Practice in graphical techniques and local forecasting. TEXT: Same as Mr 214B. PREREQUISITE: Mr 203C.

Mr 205B THE MIDDLE ATMOSPHERE (0-6). Laboratory course taught in conjunction with Mr 215B. Practice in hemispheric analysis and prognosis of contour, temperature and wind fields for constant-pressure surfaces and vertical cross sections up to 10 mb; tropopause and maximum-wind layer analysis. TEXT: Same as Mr 215B. PREREQUISITE: Mr 204B.

Mr 206C NAVAL WEATHER SERVICE ORGANIZATION AND OPERATION (1-9). Instruction and laboratory practice in the operational functions and responsibilities of the Naval Weather Service. TEXTS: Selected NavWeps, AWS and NWRF publications; departmental notes. PREREQUISITE: Mr 205B.

Mr 208B TROPICAL AND SOUTHERN HEMISPHERE METEOROLOGY (0-6). Laboratory course associated with Mr 228B. Southern hemisphere pressure analysis; low-altitude contour (isobars), streamline, and isotach analysis and forecasting with emphasis on tropical cyclones. TEXT: Departmental notes. PREREQUISITES: Mr 214B and Mr 228B.

Mr 211C ELEMENTARY WEATHER-MAP ANALYSIS (3-0). Objectives and techniques of surface and upper-air analysis, including contours (isobars), isotherms and fronts. TEXTS: Berry, Bollay, and Beers, *Handbook of Meteorology*; departmental notes. PREREQUISITES: Mr 001D and Mr 200C.

Mr 212C INTRODUCTION TO WEATHER ELEMENTS (3-0). Continuation of Mr 211C. Structure and behavior of extratropical cyclones; graphical arithmetic; stability analysis and air masses; space/time cross sections; extended analyses. TEXTS: Same as Mr 211C plus the NAWAC Manual, departmental notes. PREREQUISITE: Mr 211C.

Mr 213C FORECASTING WEATHER ELEMENTS AND MESOMETEOROLOGY (2-0). Continuation of Mr 212C. Objective forecasting techniques; quantitative forecasting of hydrometeors, temperature and wind; instability lines, tornadoes and severe weather. TEXTS: Departmental notes, various NavWeps, AWS and USWB publications. PREREQUISITE: Mr 212C.

Mr 214B UPPER-AIR AND SURFACE PROGNOSIS (3-0). Qualitative and quantitative application of mechanisms of pressure change and kinematics to surface and upper-air prognosis (up to 500 mb) of height, thickness and temperature fields. Manually applied graphical and numerical techniques; extended forecasting by weather-type methods. TEXTS: Same as Mr 213C plus Pettersen, Vol. 1, *Weather Analysis and Forecasting:* NavWeps 50-1P-548, the NAWAC Manual. PREREQUISITES: Mr 213C, Mr 301B or Mr 321A.

Mr 215B THE MIDDLE ATMOSPHERE (3-0). Objectives and techniques of high-tropospheric (above 500 mb) and stratospheric (to 10 mb) analysis and prognosis, including jet stream, maximum-wind layer and tropopause. Synoptic climatology; interpolation and extrapolation of height, temperature and wind data. TEXTS: Same as Mr 213C plus Riehl, *Jet Streams of the Atmosphere*. PREREQUISITE: Mr 214B.

Mr 217B INTERPRETIVE WEATHER FORECASTING AND PROGNOSIS (2-6). Essential operational aspects of course material contained in Mr 214B, Mr 215B. TEXTS: Same as in Mr 214B and Mr 215B. PREREQUISITES: Mr 213C and Mr 322A.

Mr 228B TROPICAL AND SOUTHERN HEMISPHERE METEOROLOGY (3-0). Southern hemisphere synoptic meteorology; tropical synoptic models (with emphasis on the tropical cyclone); tropical forecasting. TEXT: Riehl, *Tropical Meteorology*. PREREQUISITE: Mr 301B or Mr 321A.

Mr 301B ELEMENTARY DYNAMIC METEOROLOGY I (4-0). The equations of motion; trajectories and streamlines; thermal wind; mechanism of pressure changes and kinematics of pressure systems. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology*. PREREQUISITES: Mr 200C, Mr 402C, PH 191D.

Mr 302B ELEMENTARY DYNAMIC METEOROLOGY II (4-0). A continuation of Mr 301B. Vorticity and circulation; dynamical forecasting by numerical methods; selected topics including fronts and frontogenesis. TEXT: Same as Mr 301B. PREREQUISITE: Mr 301B.

Mr 321A DYNAMIC METEOROLOGY I (3-0). The equations of motion; horizontal flow; geostrophic and gradient winds; vertical variation of wind and pressure systems; kinematics of pressure systems; continuity and tendency equations. TEXT: Same as Mr 301B. PREREQUISITES: Mr 413B, Ma 240C and Ma 261B concurrently.

Mr 322A DYNAMIC METEOROLOGY II (3-0). A continuation of Mr 321A. Circulation theorems, vorticity equation and applications, solution of hydrodynamic equations by (a) perturbation methods, (b) by numerical integration; barotropic and baroclinic models; fronts and frontogenesis. TEXT: Same as Mr 301B. PREREQUISITES: Ma 125B concurrently and Mr 321A.

Mr 323A DYNAMIC METEOROLOGY III (TURBULENCE AND DIFFUSION) (3-0). Viscosity and turbulence; equations of motion for viscous and turbulent flows; wind in the friction layer; diffusion of momentum, heat, water, vapor, chemicals, etc.; diurnal temperature variation; air-mass transformation; statistical properties of turbulence. TEXTS: Same as Mr 301B plus Sutton, *Micrometeorology*. PREREQUISITES: Mr 322A and Ma 333B.

Mr 324A DYNAMICAL PREDICTION (3-3). The solution of the hydrodynamical equations for meteorological phenomena by analytical and numerical methods. Objective analysis. TEXT: Thompson, *Numerical Weather Analysis and Prediction*. PREREQUISITES: Mr 323A and Ma 128B.

Mr 325A ENERGETICS OF THE GENERAL CIRCULATION (2-0). The equations for energy and momentum balance in the atmosphere; zonal and eddy energy; adiabatic heating and its conversion into kinetic energy. Models of the general circulation. Transport of enthalpy, momentum, kinetic energy, etc., using Fourier transforms. TEXTS: Pfeffer, *Dynamics of Climate;* departmental notes. PREREQUISITES: Mr 323A and Ma 128B.

Mr 335A THEORETICAL METEOROLOGY (3-0). Advanced topics in theoretical meteorology to fit the needs of the students. PREREQUISITE: Consent of the Instructor.

Mr 402C INTRODUCTION TO METEOROLOGICAL THERMODYNAMICS (3-2). A treatment of elementary thermodynamics and its application in meteorology, with particular emphasis on thermodynamic charts and diagrams. Theories of condensation and precipitation processes. Static stability and instability phenomena. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology*. PREREQUISITES: PH 191D and Ma 052D or equivalent.

Mr 403B INTRODUCTION TO MICROMETEOROLOGY (4-0). Properties of radiating matter in general; solar and terrestrial radiation and their effects on the temperature distribution; the heat budget; structure of the wind (in the friction layer) and its significance in turbulent transfer; air-mass modification; forecasting the micrometeorological variables and their use in diffusion from point and line sources. TEXT: Same as Mr 402C. PREREQUISITES: Mr 302B and Ma 381C or equivalent.

Mr 410C METEOROLOGICAL INSTRUMENTS (2-2). Principles of design and operation of meteorological instruments used in naval meteorology with special emphasis on new developments and requirements. Application of electronic meteorological instruments used by the fleet meteorologist. TEXTS: Middleton and Spilhaus, *Meteorological Instruments;* selected papers and departmental notes. PREREQUISITES: Ma 052D or equivalent and PH 196C or equivalent.

Mr 412A PHYSICAL METEOROLOGY (3-0). Solar and terrestrial radiation; absorption, scattering and diffuse reflection of solar radiation; terrestrial radiation and the atmosphere radiation chart; applications to air-mass modification and minimum-temperature forecasting; heat budget of earth-atmosphere system. TEXTS: Same as Mr 402C; departmental notes. PREREQUISITE: Mr 413B.

Mr 413B THERMODYNAMICS OF METEOROLOGY (3-2). The physical variables; equations of state; first law of thermodynamics; properties of gases; properties of water and moist air; theories of condensation and precipitation processes; thermodynamic diagrams; air-mass identification indices; geopotential determinations; altimetry; instability phenomena and criteria. TEXTS: Same as Mr 402C; departmental notes. PREREQUISITES: Ma 230D and PH 196C.

Mr 415B RADAR METEOROLOGY (2-0). Characteristics of radar sets; propagation of electromagnetic waves in standard and non-standard atmospheres; scattering by hydrometeors; attenuation; quantitative precipitation estimates; applications of radar in convective clouds, mesometeorology and larger-scale weather systems. TEXT: Battan, *Radar Meteorology*. PREREQUISITES: Mr 321A or Mr 301B; Ma 333B or Ma 381C.

Mr 420B UPPER-ATMOSPHERE PHYSICS (4-0). The fundamental laws of atmospheric flow; balloon and rocket research; sounding the atmosphere by acoustic and radio techniques; the ozonosphere; aerial tides and magnetic effects; solar, magnetic and ionospheric disturbances, me-

teors, cosmic rays and satellites. TEXT: Massay and Boyd, *The Upper Atmosphere;* Fleagle and Businger, *An Introduction to Atmospheric Physics;* departmental notes. PREREQUISITES: PH 365C, PH 541B and PH 671B.

Mr 422A THE UPPER ATMOSPHERE (4-0). The composition of the upper atmosphere; temperature and wind structure as deduced from several lines of observation; variations of electron concentration in the ionosphere; terrestrial magnetic variations; solar disturbances and their effects in the upper atmosphere; the aurora. TEXTS: Same as Mr 420B, plus Goody, *The Physics of the Stratosphere.* PREREQUISITES: Mr 323A, and Ma 333B or Ma 381C.

Mr 510C CLIMATOLOGY (2-0). The distribution with respect to season, geography, and orography of the major meteorological elements. Definitions of climatic zones and types according to Koeppen and their meteorological descriptions; micrometeorology; regional climatology of the oceans; climatology as a tool in objective forecasting. TEXT: Landsberg, *Physical Climatology.* PREREQUISITE: Mr 200C.

Mr 521B SYNOPTIC CLIMATOLOGY (2-2). The study and statistical evaluation of meteorological elements in relation to the macro- and microclimates; the Koeppen system; methods of presenting climatological data to nonmeteorological personnel; construction and use of forecast registers; climatological techniques in objective forecasting. TEXT: Landsberg, *Physical Climatology.* PREREQUISITES: Mr 200C and Ma 381C or Ma 333B concurrently.

Mr 810B SEMINAR IN METEOROLOGY AND OCEANOGRAPHY (2-0). Students present original research or prepare summaries of recent findings in the fields of meteorology or oceanography and present synopses for group discussion. PREREQUISITES: Mr 422A or Mr 403B, Mr 521B, and Ma 333B or Ma 381C.

OCEANOGRAPHY

OC 100D SURVEY OF OCEANOGRAPHY (3-0). A description of the marine environment; the topography of the sea floor; bottom sediments; distributions of temperature, salinity and biological materials; ocean-atmosphere interactions and their influence on currents, waves and the ocean thermal structure; methods of oceanographic observation and analysis. Intended as a terminal course for students not enrolled in environmental sciences curricula. TEXT: Departmental notes. PREREQUISITE: None.

Oc 110C INTRODUCTION TO OCEANOGRAPHY (3-0). A survey course treating physical and chemical properties of sea water, marine biology, and submarine geology; the heat budget of the oceans; water masses and the general circulation; currents, waves, and tides. TEXTS: Sverdrup, *Oceanography for Meteorologists;* Shepard, *Submarine Geology.* PREREQUISITE: None.

Oc 201B OCEAN WAVES AND TIDES (3-1). The properties of waves of small amplitude in all water depths; wave spectra and analysis; refraction; near-shore circulations; tide-producing forces, tides and tidal currents, and analysis of tidal records; internal waves. TEXT: Departmental notes. PREREQUISITES: Oc 110C and PH 196C.

Oc 211A OCEAN WAVES (3-0). Various solutions of the hydrodynamical equations of motion for surface and internal waves, with particular attention to short gravity waves and their properties; generation of waves by wind; empirical and theoretical wind-wave spectra. TEXTS: Defant, *Physical Oceanography;* selected publications. PREREQUISITES: Ma 261B and Ma 333B.

Oc 212A TIDES AND TIDAL CURRENTS (3-0). Theories of the astronomical tides; the tide-producing forces; tidal oscillations in ocean basins; geographical variation of the tides; analysis and prediction of tides; tidal datum planes. Meteorological tides. Seiches. Tidal currents. TEXTS: Defant, *Physical Oceanography;* Marmer, *Tidal Datum Planes.* PREREQUISITE: Oc 211A.

Oc 213A SHALLOW-WATER OCEANOGRAPHY (3-1). Transformation of waves in shoal water; nearshore water circulation and littoral drift; beaches and coasts. TEXT: King, *Beaches and Coasts.* PREREQUISITES: Oc 110C and Oc 610B or Oc 611B (one of the latter may be taken concurrently).

Oc 220B DESCRIPTIVE OCEANOGRAPHY (3-0). Properties of sea water; water masses, currents and three-dimensional circulation in all oceans; distribution of temperatures, salinity and oxygen; temperature-salinity relationship. TEXTS: Sverdrup, Johnson and Fleming, *The Oceans;* selected references. PREREQUISITE: Oc 110C.

Oc 241B ELEMENTARY DYNAMIC OCEANOGRAPHY (3-0). The equations of motion; geostrophic currents and their calculation by the indirect method; inertial motion; vorticity; frictional effects and wind-driven currents; dynamic models of the ocean circulation. TEXT: von Arx, *Introduction to Physical Oceanography.* PREREQUISITES: Oc 110C and Mr 302B.

Oc 251A DYNAMIC OCEANOGRAPHY I (3-0). Thermodynamics of the sea; absorption of electromagnetic radiation; the equations of relative motion, the hydrostatic equation; frictionless flow. TEXT: Defant, *Physical Oceanography.* PREREQUISITES: Oc 110C, Ma 240C and Ma 251C.

Oc 252A DYNAMIC OCEANOGRAPHY II (3-0). The deep thermohaline circulation, vertical current shear, topographic influences on currents; mass transport calculations; horizontal divergence and vertical motion. TEXT: Defant, *Physical Oceanography.* PREREQUISITES: Oc 251A or Mr 321A.

Oc 253A DYNAMIC OCEANOGRAPHY III (3-0). Turbulence and diffusion in the ocean; boundary layer flow; air-sea interface exchanges; convection, stability and the formation of mixed layers; the wind-driven circulation.

TEXT: Defant, *Physical Oceanography*. PREREQUISITES: Oc 252A or Mr 321A.

Oc 260B SOUND IN THE OCEAN (3-0). The oceanographic factors involved in sound ranging, including thermal gradients, sound absorption properties of sea water, sound scattering and reflection characteristics of the sea surface and sea floor, scattering properties of marine organisms, and ambient noise arising in the sea. TEXTS: Albers, *Underwater Acoustics Handbook;* departmental notes. PREREQUISITES: Oc 110C and PH 196C or equivalent.

Oc 320B INTRODUCTION TO GEOLOGICAL OCEANOGRAPHY (3-2). Physiography of the sea floor, especially continental shelves and slopes, submarine canyons, coral reefs, and the deep-sea floor; character and distribution of sediments and rates of deposition; structure and origin of the ocean basins. TEXTS: Shepard, *Submarine Geology (2nd ed.);* Kuenen, *Marine Geology*. PREREQUISITE: Oc 110C.

Oc 330A MARINE GEOLOGY AND GEOPHYSICS (3-0). Topography and sediments of the sea floor; gravity, magnetism, and seismicity of the oceans; acoustical studies at sea; structure of the sea floor; origin of the ocean basins. For students not majoring in the environmental sciences: TEXTS: Gilluly, Waters and Woodford, *Principles of Geology;* Shepard, *Submarine Geology (2nd ed.);* selected publications. PREREQUISITE: Oc 110C.

Oc 340A MARINE GEOPHYSICS (2-0). Geophysical measurements of the earth; gravity, magnetism and seismicity of the oceans; acoustical studies of the sea floor; earth's crust beneath the ocean basins. TEXT: selected publications. PREREQUISITE: Oc 320B.

Oc 420B INTRODUCTION TO BIOLOGICAL OCEANOGRAPHY (3-2). Plant and animal groups in the oceans; character of the plankton, nekton, and benthos; marine biological environments; oceanographic factors influencing populations; the effect of organism on the physical-chemical properties of sea water; organisms responsible for sical-chemical properties of sea water; organisms responsible for boring, fouling, sound and light production, and sound scattering. TEXT: Selected publications. PREREQUISITE: Oc 110C.

Oc 520B INTRODUCTION TO CHEMICAL OCEANOGRAPHY (3-2). Chemical composition of sea water; determination and distribution of salinity, dissolved gases and plant nutrients; sea ice; production of fresh water from sea water. TEXTS: Sverdrup, Johnson and Fleming, *The Oceans;* Strickland and Parsons, *Methods in Chemical Oceanography*. PREREQUISITE: Oc 110C.

Oc 610B OCEAN WAVE FORECASTING (3-0). The generation and propagation of ocean wind waves; their spectral and statistical properties; wave observations and analysis of data; forecasting wind waves from meteorological data; applications to operations at sea. TEXTS: H. O. 603; departmental notes. PREREQUISITES: Oc 211A or Oc 201B.

Oc 611B OCEAN WAVE FORECASTING (3-6). Same as Oc 610B with laboratory exercises on the forecasting of wind waves and analysis of records. TEXTS: Same as Oc 610B. PREREQUISITES: Same as Oc 610B.

Oc 612B ARCTIC OCEANOGRAPHY (3-0). Marine geography of the Arctic; sea ice observations, formation, properties, growth, deformation and disintegration; sea ice drift due wind and currents. TEXT: *Sea Ice Manual* (unpublished). PREREQUISITES: Oc 201B and Oc 241B.

Oc 613B ARCTIC OCEANOGRAPHY (3-4). Same as Oc 612B with laboratory exercises in forecasting sea ice drift, growth and disintegration. TEXT: *Sea Ice Manual* (unpublished). PREREQUISITES: Oc 201B and Oc 241B.

Oc 615B OCEANOGRAPHIC FORECASTING I (3-4). Space/time distributions of mixed-layer thickness; diurnal variations in the vertical temperature structure. Analysis of charts of surface temperature, mixed-layer depth, temperature gradients and currents; synoptic forecasting of these elements in the laboratory. TEXTS: Selected publications. PREREQUISITE: Ma 381C.

Oc 617B OCEANOGRAPHIC FORECASTING II (3-4). Reviews variation of ocean thermal structure and processes involved; techniques in forecasting thermal structure illustrated by laboratory exercises; practice in developing forecast methods from air and sea data. Applications of oceanography in ASWEPS and other Navy operations; radar propagation. TEXTS: Laevastu, *Factors Affecting the Temperature of the Surface Layer of the Sea;* selected references. PREREQUISITES: Oc 220B, Oc 260B and Oc 615B.

Oc 619B OCEANOGRAPHIC FORECASTING (3-4). Reviews variation of ocean thermal structure and processes involved; space-time distributions of mixed layer thickness; analysis of oceanographic charts of surface temperature, temperature gradients, currents; synoptic forecasting of these elements. Applications in ASWEPS and other Navy operations. TEXTS: Laevastu, *Factors Affecting the Temperature of the Surface Layer of the Sea;* selected publications. PREREQUISITES: Oc 220B, Oc 260B and Ma 381C.

Oc 700B OCEANOGRAPHIC INSTRUMENTS AND OBSERVATIONS (2-2). Theory and operation of oceanographic instruments; instructions in recording oceanographic observations, measurements and samples on log sheets. TEXTS: H. O. 607; selected references. PREREQUISITE: Oc 220B.

Oc 720B FIELD EXPERIENCE IN OCEANOGRAPHY (0-4). Field operation of instruments to accomplish a comprehensive oceanographic survey, processing and storage of the data and samples, and interpretation of the results. TEXTS: H. O. 607; selected references. PREREQUISITE: OC 220B.

Oc 810B SEMINAR IN OCEANOGRAPHY (2-0). Students in the environmental sciences curricula conduct original research or summarize the literature in oceanography concerning a selected topic, and during their last term present their results for group discussion. PREREQUISITE: None.

Oc 820A SPECIAL TOPICS IN OCEANOGRAPHY (3-0). Lectures or seminars on topics in oceanography not contained in other courses, including a review by the student of recent research papers of significance; course taken by students in the environmental sciences curricula toward the end of their program. TEXT: Selected publications. PREREQUISITE: None.

Oc 830A SPECIAL TOPICS IN OCEANOGRAPHY (3-0). Lectures or seminars on specialized subjects in oceanography of particular interest to students enrolled in curricula other than those in the environmental sciences; taken toward the end of the student's program. TEXT: Selected publications. PREREQUISITE: Oc 110C.

DEPARTMENT OF NAVAL WARFARE

CARL C. SCHMUCK, Commander, U.S. Navy, Chairman; B.S.M.E., Purdue Univ., 1939.

H. W. BERGBAUER, JR., Lieutenant Commander, U.S. Navy; Instructor in Anti-Air Warfare; B.S., USNA, 1953.

RALPH D. BOTTEN, Commander, U.S. Navy; Instructor in Tactics and CIC; B.S., Univ. of Maryland, 1955.

RICHARD F. CAMPBELL, Lieutenant Commander, U.S. Navy; Instructor in Missiles and Space Operations; B.A., Ohio State Univ., 1960.

SHELDON DREWS, Lieutenant Commander, U.S. Navy; Instructor in Aero Engineering and Safety; B.S., USNA, 1952; USNPGS, 1960; M.S., MIT, 1961.

JAMES J. DURKIN, Lieutenant, U.S. Naval Reserve; Instructor in Tactics and CIC.

GEORGE W. FAIRBANKS, Commander, U.S. Navy; Instructor in Damage Control.

JOHN O. GINN, Commander, U.S. Navy; Instructor in Leadership.

DAVID G. HAMILTON, Lieutenant Commander, U.S. Navy; Instructor in Marine Nuclear Propulsion, Marine Engineering, Mine Warfare, and Ordnance and Fire Control; B.S., USNA, 1955; B.S., USNPGS, 1962.

EDWARD D. JACKSON, Commander, U.S. Navy; Instructor in Operational Planning, Naval Aviation Survey; B.A.E., Univ. of Mississippi, 1958.

J. R. JOHNSON, Lieutenant Commander, Supply Corps, U.S. Navy; Instructor in Logistics and Naval Supply; B.S., Univ. of Michigan, 1951; M.B.A., Univ. of Michigan, 1953.

NATHAN KING, Commander, U.S. Navy; Instructor in Naval Tactical Data System.

GLENN E. KITZELMAN, Lieutenant, U.S. Navy; Instructor in Celestial Navigation, Piloting and Seamanship; B.A., USNPGS, 1962.

ALEXANDER KOSITCH, Lieutenant Colonel, U.S. Marine Corps; Instructor in Amphibious Operations; B.S., UCLA, 1942; M.B.A., George Washington Univ., 1957.

A. J. MARGESON, Lieutenant Commander, U.S. Navy; Instructor in Anti-Submarine Warfare; B.S., Tufts Univ., 1952.

JOHN P. PRISLEY, Commander, U.S. Navy; Instructor in Anti-Submarine Warfare.

JAMES H. SMITH, Lieutenant Commander, U.S. Navy; Instructor in Amphibious Operations; B.A., Univ. of Southern California, 1960.

WILLIAM T. SORENSON, Commander, U.S. Navy; Instructor in Naval Intelligence, Personal Affairs.

LESTER C. WIBLE, Assistant Professor, Instructor in Aviation Accident Prevention and Crash Investigation; B.S., USNA, 1945.

NAVAL WARFARE

NW 101C TACTICS AND COMBAT INFORMATION CENTER (5-0). Shipboard tactical doctrine and procedures, and functions and organization of CIC. Course includes basic maneuvering board fundamentals, and introduction to operational communications doctrine, organization, and command responsibilities. Usual basis for exemption: Qualified Destroyer Type OOD underway, or CIC School of 4 weeks or longer or qualified CIC officer. Foreign officers take NW 191D.

NW 103C ANTI-SUBMARINE WARFARE (5-0). Surface, air, and sub-surface ASW doctrine. Submarine operating characteristics, offensive and defensive tactics, and weapons. ASW search, detection and attack procedures, and weapons systems. Coordinated ASW operations are emphasized. PREREQUISITE: NW 101C (or exempt therefrom). USUAL BASIS FOR EXEMPTION: Recent completion of: Coordinated ASW Course at NORFOLK, SAN DIEGO, LONDONDERRY, or HALIFAX, or ASW Officer or CO/XO Anti-Submarine Course at Fleet Sonar School. Foreign Officers take NW 193D.

NW 105C ANTI-AIR WARFARE (4-0). Study of AAW Tactical doctrine and capabilities of U.S. Naval Forces; concepts and procedures for Fast Carrier Strike Force AAW operations; future developments in AAW including command and control, weapons and communications. PREREQUISITES: NW 101C and NW 303C or exemptions therefrom.

NW 191D TACTICS AND COMBAT INFORMATION CENTER (5-0). Shipboard tactical doctrine and procedures, and functions and organization of CIC. Foreign Officers course.

NW 193D ANTI-SUBMARINE WARFARE (3-0). Surface, air, sub-surface ASW doctrine. Submarine operating characteristics, offensive and defensive tactics, and weapons. ASW search, detection and attack procedures, and weapons systems. PREREQUISITE: NW 191D (or exempt therefrom). Foreign Officers course.

NW 201C OPERATIONAL PLANNING (2-0). Purpose and procedure for the Estimate of the Situation, the Development of the Plan, and the Preparation of the Directive (OpOrder); including the preparation of each under supervision. Staff organization. The Navy Planning System. USUAL BASIS FOR EXEMPTION: Naval War College Correspondence course "Strategy and Tactics (Part I)" or "Operational Planning and Staff Organization."

NW 205C NAVAL WARFARE SEMINAR (3-0). A survey of current operations and concepts for the future in the various tactical and strategic fields of Naval Operations, together with an orientation in the history and background of insurgency movements and the nature of counter insurgency operations. In addition, students will participate as small groups in the research and study of selected subjects of direct Naval interest, presenting their findings in seminars.

NW 206C AERO ENGINEERING AND SAFETY I (3-0). A survey of aeronautical engineering for the aviator and the Aviation Safety Officer. Material covered includes basic aerodynamics, subsonic and supersonic aircraft characteristics, aircraft performance, stability and control, and aircraft structural limitations.

NW 207C AERO ENGINEERING AND SAFETY II (3-0). Continuation of NW 206C Aero Engineering and Safety I. PREREQUISITE: NW 206C.

NW 208C AVIATION ACCIDENT PREVENTION AND CRASH INVESTIGATION (5-0). This course consists of (a) a study of all existing Navy Department instructions covering all aspects of accident investigation and reporting procedures, (b) methods and techniques of accident investigation, (c) implementation and use of a prevention program, and (d) aero medicine lectures on physiological factors in flight.

NW 292D AMPHIBIOUS OPERATIONS (4-0). Basic Orientation, to include doctrine, planning and fundamentals of troop organization, helicopter operations, embarkation, ship-to-shore movement, and coordination of supporting arms. USUAL BASIS FOR EXEMPTION: Completion of a Marine Corps or Amphibious Forces School and/or a tour of duty with an amphibious staff at PhibRon level or higher. Foreign officer course.

NW 293D NAVAL AVIATION SURVEY (3-0). Organizational structure and command relationship of entire naval aviation system; research and development, procurement, testing and evaluation of naval aircraft; specific discussions based on latest material available on missions, tasks, current and projected equipment, as well as present and future employment of aircraft squadrons, carriers and seaplane tenders. USUAL BASIS FOR EXEMPTION: Extensive aviation duty. Foreign officer course.

NW 303C MISSILES AND SPACE OPERATIONS (4-0). Principles of guidance and propulsion, operational capabilities and limitations of guided missile systems. Orientation in space technology, problems and potentialities of operations in outer space. USUAL BASIS FOR EXEMPTION: Equivalent experience or educational background. Foreign officers take NW 393D.

NW 304C INTRODUCTION TO NAVAL TACTICAL DATA SYSTEM (2-0). A brief review of number systems with concentration in octal and binary operations. An introduction to Boolean algebra and logic circuitry of modern computers. Modern high-speed digital computer principles. An introduction to operational programming for NTDS. A comprehensive coverage of the Naval Tactical Data System and its associated elements, its capabilities and limitations as planned for CVA(N), CG(N) and DLG types.

NW 391D ORDNANCE-WEAPON SYSTEMS (3-0). A survey of the fields of surface ordnance, including guns, ammunition, and associated fire control systems. An analysis of weapon systems capabilities and limitations. Foreign officers course.

NW 393D MISSILES AND SPACE OPERATIONS (3-0). Principles of guidance and propulsion. Orientation in space technology, problems and potentialities of operations in outer space. Foreign officers course.

NW 395D MINE WARFARE (3-0). Fundamentals of mine laying and mining planning. Principles of mine countermeasures operations, planning, and harbor defense. Foreign officers course.

NW 401C LEADERSHIP AND ADMINISTRATION (3-0). The improvement of Naval Leadership by broadening the line officer's knowledge and understanding of the following topics: methods and techniques of enlisted personnel administration; applications of the principles of management to the naval unit; philosophy of authority and responsibility with major emphasis on the principles of effective naval leadership. Instruction methods emphasize individual study projects and group study discussion.

NW 403C CELESTIAL NAVIGATION (3-0). The theory and practice of celestial navigation as applicable to the navigator's work at sea. Included topics: introduction to nautical astronomy; the use of the nautical almanacs and the H. O. 214; the applications of celestial navigation. Practical work covers the navigator's day's work at sea.

NW 404C LOGISTICS AND NAVAL SUPPLY (3-0). The initial phase of the course stresses the importance of military logistics to our national security. Topics covered are: the fundamental elements of the logistics process; the planning, programming, and organizational aspects of logistical administration; the budget process; and joint logistical procedures. The final phase of the course emphasizes naval logistics and its relationship to combat readiness. Topics included are: the Navy Supply System; the role of bases, mobile support, and the operating unit in naval logistics; and logistics management at the unit command level.

NW 405D PERSONAL AFFAIRS (3-0). The fundamentals of personal estate planning. Included topics: government benefits; life insurance and general insurance; budgeting and banking; borrowing; real estate; securities; wills, and related legal matters.

NW 407D NAVAL INTELLIGENCE (3-0). An overview of intelligence functions. Included topics: nature of intelligence; development of modern intelligence; the role of intelligence in planning national policy and military strategy; the rise of Russia and Communism as international forces; the intelligence cycle, including the line officer's role in intelligence collection; employment of intelligence by operational commanders; counterintelligence.

NW 408C SEAMANSHIP AND MARINE PILOTING (3-2). The fundamentals of seamanship as applicable to the responsibilities and duties assigned to the commanding

officer of a naval vessel. Practical aspects of shipboard navigation, including marine piloting, radar and loran navigation. Practical work covers the use of hydrographic publications and performance of chart work. USUAL BASIS FOR EXEMPTION: Successful completion of USNA, NROTC, OCS or equivalent course; or previous assignment as navigator (assistant navigator of a large ship) for one year.

NW 502C DAMAGE CONTROL AND ATOMIC BIOLOGICAL, CHEMICAL WARFARE DEFENSE (4-0). Fundamentals of ship construction and stability, stability calculations and analysis, damage control systems and organization, repair of damage; effects of ABC weapons, ABC detection, decontamination and personnel protection; disaster control ashore. USUAL BASIS FOR EXEMPTION: Completion of 10 weeks "Officers' Basic Damage Control" Course, or completion of correspondence courses "Practical Damage Control" (NAVPERS 10936), "Theoretical Damage Control" (NAVPERS 10937), and "Radiological Defense" (NAVPERS 10771).

NW 503C MARINE NUCLEAR PROPULSION (2-0). An introduction to nuclear power plants of possible use in marine propulsion. Includes principles of operation, fuels and materials, limitations and economy of various reactors, and a brief description of reactor power plants currently in use.

NW 591D MARINE ENGINEERING (4-0). Shipboard steam and diesel main propulsion plants and auxiliaries, shipboard electrical distribution, miscellaneous naval auxiliary machinery, and organization and administration of shipboard engineering department. USUAL BASIS FOR EXEMPTION: Qualification as Engineering Officer of the Watch of a steam-propelled ship. Foreign officer course.

DEPARTMENT OF OPERATIONS ANALYSIS

Jack Raymond Borsting, Professor of Operations Research, Chairman (1959); B.A., Oregon State Univ., 1951; M.A., Univ. of Oregon, 1952; Ph.D., 1959.

Alvin Francis Andrus, Associate Professor of Operations Research (1963); B.A., Univ. of Florida, 1957; M.A., 1958.

Robert Naegle Forrest, Associate Professor of Operations Research (1964); B.S., Univ. of Oregon, 1950; M.S., 1952; M.S., 1954; Ph.D., 1958.

Carl Russell Jones, Associate Professor of Operations Research (1965); B.S., Carnegie Institute of Technology, 1956; M.B.A., Univ. of Southern California, 1963; Ph.D., Claremont Graduate School, 1965.

Thomas Edmond Oberbeck, Professor of Operations Research (1951); B.A., Washington Univ., 1938; M.A., Univ. of Nebraska, 1940; Ph.D., California Institute of Technology. On leave of absence.

Samuel Howard Parry, Instructor of Operations Research, (1964); B.I.E., Georgia Institute of Technology, 1963; M.S. Northwestern Univ., 1964.

Stephen Michael Pollock, Assistant Professor of Operations Research (1965): B.E.P., Cornell Univ., 1958; M.S., Massachusetts Institute of Technology, 1960; Ph.D., 1964.

Rex Hawkins Shudde, Associate Professor of Operations Research (1962); B.S., B.A., Univ. of California at Los Angeles, 1952; Ph.D., Univ. of California, 1956.

Hans Jacob Zweig, Associate Professor of Operations Research (1965); B.A., Univ. of Rochester, 1949; M.A., Brown Univ., 1951; Ph.D., Stanford Univ., 1963.

*The year of joining the Postgraduate School faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREE IN OPERATIONS RESEARCH

BACHELOR OF SCIENCE

The basic requirement for the degree Bachelor of Science with major in Operations Research consists of a minimum of 64 term hours in residence at the Postgraduate School and including at least:

a. 24 term hours of Operations Research
b. 15 term hours of Probability and Statistics
c. 10 term hours of Mathematics beyond elementary Calculus
d. 10 term hours of upper division Physical Science, Engineering, or Management courses.

The degree of Bachelor of Science with major in Operations Research will be granted to a student who has successfully completed the above requirements and can demonstrate that he has met the general requirements of the Naval Postgraduate School for a Bachelor of Science degree.

MASTER OF SCIENCE IN OPERATIONS RESEARCH

In order to qualify for the degree Master of Science in Operations Research in accordance with the requirements listed below, a student must first meet the requirements for the degree Bachelor of Science with major in Operations Research. Specific course requirements include a minimum of 48 term hours of A and B level courses of which:

a. At least 18 term hours must be in A level Operations Research courses including: Linear Programming, Dynamic Programming and Queueing Theory.
b. At least 12 term hours must be in advanced physics courses.
c. At least one of the sequences of elective courses recommended by the Department of Operations Analysis.

In addition a student must submit a thesis on a subject approved by the Department of Operations Analysis and demonstrate that he has met the general requirements of the Naval Postgraduate School for a Master of Science degree.

OPERATIONS ANALYSIS

OA 001E ORIENTATION IN OPERATIONS ANALYSIS CURRICULUM (0-1). A review of objectives of the Operations Analysis Curriculum: definitions of operations analysis and operations research: origins and contemporary status of operations research: the role of operations research in the development of weapons systems. TEXTS: McCloskey and Trefethen, *Operations Research for Management*, Vols. I and II; Instructor's Notes.

OA 101C ELEMENTS OF OPERATIONS RESEARCH/SYSTEMS ANALYSIS (4-1). An introductory course primarily for students in the Engineering Science Curriculum. Topics covered include: nature, origin, and contemporary status of operations analysis: problem formulations, measures of effectiveness; brief introduction to linear programming, game theory, and system reliability. TEXTS: McCloskey and Trefethen, *Operations Research for Management*, Vols. I and II; Sasieni, *Operations Research Methods and Problems:* Instructor's Notes. PREREQUISITE: Ma 311C.

OA 111B PRINCIPLES OF OPERATIONS RESEARCH/SYSTEMS ANALYSIS (4-2). An introductory course, primarily for students in the Management Data Processing Curriculum. The definition of operations and systems analysis and its relation to management science. Topics include: Linear Programming, Game Theory, Reliability Theory, and Dynamic Programming. TEXTS: McCloskey and Trefethen, *Operations Research for Management*, Vols. I and II; Blackett, *Studies of War;* Gass, *Linear Programming;* Williams, *The Compleat Strategyst;* Lloyd and Lipow, *Reliability;* Bellman and Dreyfus, *Applied Dynamic Programming.* PREREQUISITES: Ma 140B or its equivalent; Ma 315C or its equivalent; Ma 316B or its equivalent (may be taken concurrently).

OA 112A ADVANCED METHODS IN OPERATIONS ANALYSIS (4-0). A continuation of OA 111B. A survey of such techniques as queueing theory, inventory control, simulation and Monte Carlo methods, computer gaming, statistical decision theory, and a selected case study in systems analysis. TEXTS: To be announced. PREREQUISITES: OA 111B and a second course in probability and statistics to be taken concurrently.

OA 121A PRINCIPLES OF OPERATIONS ANALYSIS (4-1). The nature, origin, and contemporary status of operations analysis; fundamental concepts with special emphasis on applications; introduction to game theory, search theory, linear programming, and other advanced techniques. TEXTS: Morse and Kimball, *Methods of Operations Research;* McCloskey and Trefethen, *Operations Research for Management,* Vols. I and II; Gass, *Linear Programming;* Hitch and McKean, *The Economics of Defense in the Nuclear Age.* PREREQUISITES: Ma 321B and Ma 322A.

OA 141B FUNDAMENTALS OF OPERATIONS RESEARCH/SYSTEMS ANALYSIS (4-1). The role of operations analysis in the solution of military problems. Measures of effectiveness. Special techniques such as search theory, game theory and linear programming. TEXTS: McCloskey and Trefethen, *Operations Research for Management,* Vols. I and II; Gass, *Linear Programming;* Hitch and McKean, *The Economics of Defense in the Nuclear Age.* PREREQUISITE: Ma 321B.

OA 202A ECONOMETRICS (3-0). An introduction to the construction and testing of econometric models, analysis of economic time series and the use of multivariate statistical analysis in the study of economic behavior. TEXTS: To be announced. PREREQUISITES: Mn 436A and Ma 304B.

OA 211A LINEAR PROGRAMMING (4-1). Mathematical methods in logistics, with major emphasis on applications of linear programming to problems of transportation and the scheduling of inter-dependent activities. Relation of linear programming to the theory of games. Laboratory work on the computation of optimal solutions to linear programming problems, including the use of high-speed digital computers. TEXTS: Hadley, *Linear Programming;* Gass, *Linear Programming.* PREREQUISITES: OA 391B and Ma 196B.

OA 212A NONLINEAR AND DYNAMIC PROGRAMMING (3-1). Introduction to modern optimization techniques and multistage decision processes. Topics include: integer linear programming, quadratic programming, Kuhn-Tucker theory and dynamic programming. TEXTS: Bellman, *Dynamic Programming;* Bellman and Dreyfus, *Applied Dynamic Programming;* Hadley, *Nonlinear and Dynamic Programming;* Bellman, *Adaptive Control Processes.* PREREQUISITE: OA 211A.

OA 213A INVENTORY CONTROL (3-0). The study of deterministic and stochastic inventory-type decision processes. Optimal policies will be derived for increasingly complicated inventory models. Emphasis will be placed on the criterion functions and their sensitivity to changes in model structure. TEXTS: Hanssmann, *Operations Research in Production and Inventory Control;* Arrow, Karlin, Scarf, *Studies in the Mathematical Theory of Inventory and Production;* Brown, *Statistical Forecasting for Inventory Control;* Bellman, *Dynamic Programming.* PREREQUISITE: OA 212A.

OA 214A GRAPH THEORY (3-0). Elements of the theory of graphs, with emphasis on applications to the study of organizations, communication systems, and transportation networks. TEXTS: Berge, *The Theory of Graphs and Its Applications;* Ore, *Theory of Graphs;* Ford and Fulkerson, *Flows in Networks.* PREREQUISITES: Ma 196B and Ma 193C.

OA 215A GRAPH THEORY II (3-0). A continuation of OA 214A. TEXTS: Berge, *The Theory of Graphs and Its Applications;* Ore, *Theory of Graphs;* Ford, and Fulkerson, *Flows in Networks.* PREREQUISITE: OA 214A.

OA 216A CYBERNETICS (3-0). This course deals with the problems of controlling very complex systems by feedback and "black boxes." Contributions to the theory of cybernetics from logic, biophysics, and other sources are developed. Applications are made to mechanical, social, and mental systems. TEXTS: W. R. Ashby, *An Introduction to Cybernetics;* S. Beer, *Cybernetics and Management.* PREREQUISITES: OA 291C and OA 292B.

OA 217A THEORY OF PATTERN RECOGNITION (3-0). Survey of principles governing the design of pattern recognition and detection devices of both the adaptive and non-adaptive type. Elements of learning theory; separability of object space using quadratic and linear decision functions; convergence of deterministic and stochastic adaptive techniques; survey of important, concrete applications. TEXTS: Instructor's notes and selected papers from technical journals. PREREQUISITE: Ma 307A or equivalent.

OA 225A AIR WARFARE (3-0). Analyses of fleet air defense exercises. Changes in tactics and force disposition arising from the introduction of nuclear weapons and missiles. Active and passive air defense. Relationship of air defense to strike capability and ASW. TEXT: Classified official publications. PREREQUISITES: OA 292B and OA 293B.

OA 234A QUEUEING THEORY (3-0). Basic principles of stochastic processes applied to a class of queueing models: connection between Poisson and exponential distributions; derivation of queue length and waiting time distributions for single and parallel channel models. TEXT: Cox and Smith, *Queues.* PREREQUISITE: Ma 304B.

OA 235A DECISION CRITERIA (3-0). Survey and critique of the current literature dealing with decision criteria. Philosophy of values and allocation of effort. Applications to problems of human relations. TEXT: Luce and Raiffa, *Games and Decisions.* PREREQUISITE: OA 292B.

OA 236A UTILITY THEORY (3-0). General concept of utility and its measurement. Survey and critique of the current literature dealing with the concept and measurement of utility. Applications to problems of human relations. TEXTS: Davidson, Supper, Siegel, *Decision Making;* Churchman, *Prediction and Optimal Decision;* Hagen, *Theory of Social Change;* Thorp, *Biology and the Nature of Man.* PREREQUISITE: OA 292B.

OA 237A UTILITY THEORY II (3-0). The philosophy of measurement. The relation between the concept of utility and parallel concepts in psychophysics. The relation between utility and social philosophy. The selection and procurement of data necessary for social decisions. The first part of this course is based on a suitable text; but the main part of this course consists of student reports on the current literature. TEXT: C. W. Churchman and P. Ratoosh, *Measurement.* PREREQUISITE: OA 236A.

OA 291C INTRODUCTION TO OPERATIONS ANALYSIS (4-0). Development of fundamental concepts of operations and system analysis. Concepts of operations analysis illustrated in depth in the fields of submarine and antisubmarine warfare. Overall measures of effectiveness of a submarine as a weapon system. Determination of effectiveness as a product of measures of detection, attack, and kill probabilities. Lanchester's equations. TEXTS: Blackett, *Studies of War;* McCloskey and Trefethen, *Operations Research for Management,* Vols. I and II; Morse and Kimball, *Methods of Operations Research;* Shudde, *Introduction to Military Operations Research,* USNPGS Notes. PREREQUISITES: Ma 302B and Ma 182C (both may be taken concurrently).

OA 292B METHODS OF OPERATIONS RESEARCH/SYSTEMS ANALYSIS (4-0). The methodologies and objectives of operations research and systems analysis. Topics include: reliability theory, PERT and PERT/COST networks, air warfare, recent developments in operations research and systems analysis. TEXTS: Lloyd and Lipow, *Reliability Theory;* Ackoff, *Progress in Operations Research,* Vol I; Hertz and Eddison, *Progress in Operations Research,* Vol. II; Hitch and McKean, *The Economics of Defense in the Nuclear Age.* PREREQUISITES: OA 291C and Mn 211C.

OA 293B SEARCH THEORY (4-0). Detection devices and their characteristics. Sweep rates and lateral range curves. Evaluation of search radars. Theories of radar detection. The design of screen and barrier patrols. Allocation of search effort. TEXTS: Morse and Kimball, *Methods of Operations Research;* Koopman, *Search and Screenings;* Classified publications. PREREQUISITE: OA 292B.

OA 296A DEVELOPMENT OF WEAPONS SYSTEMS (3-0). The areas of application of the various techniques of operations research which the student has learned are reviewed and placed in perspective relative to the procedure for evolving new weapons systems. Emphasis is placed upon the role of operations research in formulating operational requirements, developing prototype systems, and determining military specifications for selected systems and the role of operations analysis in various phases of operational testing of the system. The contributions of operations research to the coordination of the functions of those segments of the military establishment concerned with weapons systems development are analyzed. TEXTS: Classified official publications and instructor's notes. PREREQUISITE: OA 211A.

OA 297A SELECTED TOPICS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS I (2-0 to 5-0). Presentation of a wide selection of reports from the current literature. At the end of the term an attempt will be made to summarize the philosophy and principal methodologies of operations research. TEXT: None. PREREQUISITE: A background of advanced work in operations research.

OA 298A SELECTED TOPICS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS II (2-0 to 5-0). A continuation of OA 297A. TEXT: None. PREREQUISITE: A background of advanced work in operations research.

OA 299A SELECTED TOPICS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS III (2-0 to 5-0). A continuation of OA 298A. TEXT: None. PREREQUISITE: A background of advanced work in operations research.

OA 391B GAMES OF STRATEGY (3-2). Two-person zero-sum games, the minimax theorem. Methods of solving finite games. Specific games with appropriate application. Methods of solving continuous games on unit square with continuous payoff functions. Applications. TEXTS: Dresher, *Theory and Applications of Games of Strategy;* Luce and Raiffa, *Games and Decisions;* McKinsey, *Introduction to the Theory of Games.* PREREQUISITES: Ma 301C or the equivalent; Ma 196B. (The latter may be taken concurrently).

OA 392A DECISION THEORY (3-0). Basic concepts. Bayes, admissible, minimax and regret strategies. Principles of choice. Applications in the planning of operational evaluation trials. TEXTS: To be announced. PREREQUISITES: Ma 304B and OA 391B. (The latter may be taken concurrently.)

OA 393B INTRODUCTION TO WAR GAMING (2-2). Simulation and Monte Carlo techniques employing manual and computer methods; random number generation; analysis of results of war games. TEXTS: Instructor's notes and prepared handouts. PREREQUISITES: OA 291B, Ma 303B, OA 421C or consent of the instructor.

OA 394A WAR GAMING (2-2). Consideration of the problems inherent in the construction and use of manual and computer war games. Problems in the analysis of results of such games. Utilization of decision laboratory techniques. Construction of simulations. TEXT: Instructor's notes and classified official publications. PREREQUISITE: OA 393B or consent of the instructor.

OA 396A ADVANCED PROJECTS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS I (2-0 to 5-0). A

course in solving special problems by the use of advanced techniques of Operations Research. Emphasis is upon extending the student's ability to formulate and solve sophisticated models of problems arising in Operations Research/Systems Analysis. TEXT: None. PREREQUISITE: Consent of the instructor.

OA 397A ADVANCED PROJECTS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS II (2-0 to 5-0). Continuation of OA 396A. TEXT: None. PREREQUISITE: Consent of the instructor.

OA 398A ADVANCED PROJECTS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS III (2-0 to 5-0). Continuation of OA 397A. TEXT: None. PREREQUISITE: Consent of the instructor.

OA 399A ADVANCED PROJECTS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS IV (2-0 to 5-0). Continuation of OA 398A. TEXT: None. PREREQUISITE: Consent of the instructor.

OA 421C INTRODUCTION TO DIGITAL COMPUTERS (5-0). Description of general purpose digital computers and peripheral equipment; data processing and problem formulation with emphasis on military environment. Binary and octal number systems. Basic FORTRAN and CODAP programming. TEXTS: McCracken, *Digital Computer Programming;* McCracken, *A Guide to FORTRAN Programming;* Organick, *A FORTRAN Primer;* Selected Control Data Corporation 1604 Manuals. PREREQUISITES: None.

OA 471B OPERATIONS ANALYSIS FOR NAVY MANAGEMENT (4-0). The nature, origin and contemporary status of operations analysis. Fundamental concepts with special emphasis on application in the fields of transportation, inventory control and personnel management. Introduction to game theory. TEXTS: McCloskey and Trefethen, *Operations Research for Management*, Vols. I and II; Gass, *Linear Programming;* Williams, *Complete Strategyst;* Chernoff and Moses, *Elementary Decision Theory.* PREREQUISITE: Ma 371C.

OA 491B METHODS FOR COMBAT DEVELOPMENT EXPERIMENTATION (4-0). Introduction to the planning, analysis and reporting aspects of tactical field experiments, Examination of criteria from the military and statistical points of view. Discriminant Analysis. TEXT: None. PREREQUISITES: OA 291C and Ma 304B.

OA 501A INTRODUCTION TO SYSTEMS ANALYSIS (4-0). A survey of military economic problems including the determination of the total budget level and its allocation among the services and weapons systems. TEXT: Hitch and McKean, *The Economics of Defense in the Nuclear Age.* PREREQUISITE: MN 413A.

OA 502A SYSTEMS ANALYSIS (4-0). Detailed examination of resources allocation among weapons systems. Examination of criteria problems, the treatment of intangibles, spillovers, uncertainty and related problems. The use of mathematical, statistical and economic methods to arrive at "preferred," if not optimum allocation decisions. TEXT: Quade, *An Appreciation of Analysis for Military Decisions,* plus current systems studies. PREREQUISITE: OA 501A.

OA 891E SEMINAR I (0-2). Review of summer assignments; selection of thesis topics; special lectures. TEXT: None.

OA 892E SEMINAR II (0-2). A continuation of OA 891E. Special lectures. TEXT: None. PREREQUISITE: None.

OA 893E SEMINAR III (0-2). Presentation of thesis developments. Special lectures. TEXT: None. PREREQUISITE: None.

OA 894E SEMINAR IV (0-2). A continuation of OA 893E. TEXT: None. PREREQUISITE: None.

OA 899E MILITARY SCIENCE SEMINAR (0-1). Review of contemporary writings on the history and developments of science in the military profession.

DEPARTMENT OF PHYSICS

EUGENE CASSON CRITTENDEN, JR., Professor of Physics, Chairman (1953)*; B.A., Cornell Univ., 1934; Ph.D., 1938.

ROBERT LOUIS ARMSTEAD, Assistant Professor of Physics (1964); B.S., Univ. of Rochester, 1958; Ph.D., Univ. of California at Berkeley, 1965.

FRANZ AUGUST BUMILLER, Professor of Physics (1962); M.S., Univ. of Zurich, 1951; Ph.D., 1955.

FRED RAMON BUSKIRK, Associate Professor of Physics (1960); B.S., Western Reserve Univ., 1951; Ph.D., Case Institute of Technology, 1958.

ALFRED WILLIAM MADISON COOPER, Associate Professor of Physics (1957); B.A., Univ. of Dublin, 1955; M.A., 1959; Ph.D., The Queen's University of Belfast, 1961.

JOHN NIESSINK COOPER, Professor of Physics (1956); B.A., Kalamazoo College, 1935; Ph.D., Cornell Univ., 1940.

ALAN BERCHARD COPPENS, Assistant Professor of Physics (1964); B.Eng.Phy., Cornell Univ., 1959; M.S., Brown Univ., 1962; Ph.D., Brown Univ., 1965.

PETER PIERCE CROOKER, Instructor in Physics (1960); B.S., Oregon State College, 1959.

WILLIAM PEYTON CUNNINGHAM, Professor of Physics (1946); B.S., Yale Univ., 1928; Ph.D., 1932.

HARVEY ARNOLD DAHL, Assistant Professor of Physics (1964); B.S., Stanford Univ., 1951; Ph.D., 1963.

JOHN NORVELL DYER, Associate Professor of Physics (1961); B.A., Univ. of California, 1956; Ph.D., 1960.

AUSTIN ROGERS FREY, Professor of Physics (1946); B.S., Harvard Univ., 1920; M.S., 1924; Ph.D., 1929.

HARRY ELIAS HANDLER, Professor of Physics (1958); B.A., Univ. of California at Los Angeles, 1949; M.A., 1951; Ph.D., 1955.

JACK R. HARRIS, Lieutenant Commander, U.S. Navy; Instructor in Physics (1964); B.S., Univ. of Michigan, 1952; M.S., Electronic Engineering, U.S. Naval Postgraduate School, 1960.

DON EDWARD HARRISON, JR., Associate Professor of Physics (1961); B.S., College of William and Mary, 1949; M.S., Yale Univ., 1950; Ph.D., 1953.

OTTO HEINZ, Associate Professor of Physics (1962); B.A., Univ. of California, 1948; Ph.D., 1954.

WILLIAM LEWIS JOHNSON, Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Physics (1963); B.S., Univ. of Southern Mississippi, 1962.

SYDNEY HOBART KALMBACH, Professor of Physics (1947); B.S., Marquette Univ., 1934; M.S., 1937.

RAYMOND LEROY KELLY, Associate Professor of Physics (1960); B.A., Univ. of Wichita, 1947; M.S., Univ. of Wisconsin, 1949; Ph.D., 1951.

LAWRENCE EDWARD KENSLER, Professor of Physics (1946); B.S., California Institute of Technology, 1931; Ph.D., 1934.

WILLIAM L. MCCOY, Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Physics (1964); B.S., Univ. of Rochester, 1963; M.S., Univ. of Illinois, 1964.

HERMAN MEDWIN, Professor of Physics (1955); B.S., Worcester Polytechnic Institute, 1941; M.S., Univ. of California at Los Angeles, 1948; Ph.D., 1953.

EDMUND ALEXANDER MILNE, Associate Professor of Physics (1954); B.A., Oregon State College, 1949; M.S., California Institute of Technology, 1950; Ph.D., 1953.

JOHN ROBERT NEIGHBOURS, Professor of Physics (1959); B.S., Case Institute of Technology, 1949; M.S., 1951; Ph.D., 1953.

NORMAN LEE OLESON, Professor of Physics (1948); B.S., Univ. of Michigan, 1935; M.S., 1937; Ph.D., 1940.

LEONARD OLIVER OLSEN, Professor of Physics (1960); B.A., Iowa State Teachers College, 1932; M.S., State Univ. of Iowa, 1934; Ph.D., 1937.

GEORGE WILL PFEIFFENBERGER, Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Physics (1964); B.S., Univ. of Notre Dame, 1962; M.S., State Univ. of Iowa, 1964.

WILLIAM REESE, Assistant Professor of Physics (1963); B.A., Reed College, 1958; M.S., Univ. of Illinois, 1960; Ph.D., 1962.

JOHN DEWITT RIGGIN, Professor of Physics (1946); B.S., Univ. of Mississippi, 1934; M.S., 1936.

GEORGE WAYNE RODEBACK, Associate Professor of Physics (1960); B.S., Univ. of Idaho, 1943; M.S., Univ. of Illinois, 1947; Ph.D., 1951.

JAMES VINCENT SANDERS, Assistant Professor of Physics (1961); B.S., Kent State Univ., 1954; Ph.D., Cornell Univ., 1961.

GORDON EVERETT SCHACHER, Assistant Professor of Physics (1964); B.S., Reed College, 1956; Ph.D., Rutgers, 1962.

ROY PRENTIS WILLIAMS, JR., Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Physics (1964); B.S., Tulane Univ., 1962; M.S., 1964.

OSCAR BRYAN WILSON, JR., Professor of Physics (1957); B.S., Univ. of Texas, 1944; M.A., Univ. of California at Los Angeles, 1948; Ph.D., 1951.

WILLIAM BARDWELL ZELENY, Associate Professor of Physics (1962); B.S., Univ. of Maryland, 1956; M.S., Syracuse Univ., 1958; Ph.D., 1960.

*The year of joining the Postgraduate School faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREE IN PHYSICS

BACHELOR OF SCIENCE IN PHYSICS

1. It is required that any specific curriculum must be consistent with the general minimum requirements for any degree of Bachelor of Science as determined by the Academic Council.

2. A major in physics must include a minimum of 54 term hours in physics, including required courses and electives, a minimum of 38 term hours in mathematics, and the equivalent of a course in general chemistry. In addition, a minimum of 20 term hours of elective credits must be chosen in other specified areas. 108 term hours must be clearly of upper division level.

3. The following requirements must be met: (courses marked with an asterisk must include a laboratory)

Discipline	*Subject*	*Approximate Term Hours*
Physics	General Physics*	16
	Physical Optics*	5
	Analytical Mechanics	8
	Electricity and Magnetics	8
	Atomic Physics*	7
		44
Mathematics	College Algebra and Trigonometry	5
	Analytic Geometry and Calculus	13
	Differential Equations	3
	Infinite Series	3
	Vector Algebra and Vector Analysis	6
		30
Chemistry	General Chemistry*	10

4. The remaining required hours in physics and mathematics are elective and must be of clearly upper division level. By choosing appropriate elective sequences in physics the student can begin a specialty-area on the undergraduate level. Suggested elective courses in physics are: Thermodynamics, Statistical Mechanics, Physics of the Solid State, Nuclear Physics, and Acoustics; in mathematics are: Complex Variables, Partial Differential Equations, and Probability and Statistics.

20 term hours of electives must be chosen in the areas of (a) electric circuits, (b) electronics, and (c) chemistry beyond general chemistry. At least 10 of the 20 term hours must be from one of these three areas.

5. The student must maintain grade point averages of at least 1.0 in both physics and mathematics.

MASTER OF SCIENCE IN PHYSICS

1. It is required that any specific curriculum be consistent with the general minimum requirements for any degree of Master of Science as determined by the Academic Council.

2. Each student's program of study must have a minimum of 36 term hours of physics *courses* not including thesis distributed between A and B level; of this 36 hours, a minimum of 12 hours must be A level. In lieu of the preceding requirement, students who are qualified to pursue graduate courses in physics when they arrive at the Postgraduate School may complete a minimum of 24 hours entirely of A level courses. In addition, all students must register for research and present an acceptable thesis.

3. The following specific course requirements must be successfully completed for a student to earn the degree of M.S. in Physics:

a. Thermodynamics and Statistical Mechanics—The student must take a two-term sequence (for example, PH 530 and PH 541) or present equivalent undergraduate preparation in this subject matter area.

b. Advanced Mechanics and Hydrodynamics—for example, PH 153 or PH 161.

c. Special Topics in Electromagnetism—for example, PH 367.

4. The student will he expected to specialize in one of the available options such as: (a) Acoustics, (h) Nuclear Physics, (c) Plasma Physics, (d) Solid State Physics, or (e) other recognized Physics specialization.

PHYSICS

PH 001D GENERAL PHYSICS I (4-0). Mechanics—The purpose of this course as well as the following 3 units is to provide a knowledge of the principles of physics and thus to help the student understand the scientific background of modern civilization. The first unit deals with physical quantities and the concepts of motion, force, momentum and energy. TEXT: Smith and Cooper, *Elements of Physics.*

PH 002D GENERAL PHYSICS II (4-0). Harmonic Motion, Sound and Heat—This is a continuation of PH 001D and considers simple harmonic motion, oscillating systems including those producing sound, the propagation of sound and wave motion. The mechanics of gases, thermometry, transfer of heat, and thermodynamics are among other topics considered. TEXT: Smith and Cooper, *Elements of Physics.* PREREQUISITE: PH 001D.

PH 003D GENERAL PHYSICS III (4-0). Electricity and Magnetism. This is a further continuation of General Physics I and II and presents the subject of electrostatics, including Coulomb's Law, potential and capacitance, electric current and electric circuits, magnetics, and induced electromotive force. TEXT: Smith and Cooper, *Elements of Physics.* PREREQUISITES: PH 001D and PH 002D.

PH 004D GENERAL PHYSICS IV (4-0). Light and Modern Physics. This is the final unit of a four-term sequence of General Physics and treats selected topics in light including the geometrical optics of mirrors and lenses, interference and diffraction and optical instruments. A brief introduction to modern physics is also given. This includes

the topics of atomic structure, optical and X-ray spectra, radioactivity, and nuclear structure. TEXT: Smith and Cooper, *Elements of Physics*. PREREQUISITES: PH 001D, PH 002D, and PH 003D.

PH 006D SURVEY OF PHYSICS (5-0). An introduction to the fundamental concepts and laws of statics and dynamics, including Newton's laws of motion, force, energy, momentum, and harmonic motion. Survey of gas laws, heat, wave propagation, sound and the properties of light. USUAL BASIS FOR EXEMPTION: Equivalent educational background. TEXT: White, *Modern College Physics*, 3rd ed. PREREQUISITE: Ma 010D or equivalent.

PH 007D GENERAL PHYSICS I (3-2). Similar to PH 001D but laboratory is included. TEXT: Smith and Cooper, *Elements of Physics*.

PH 008D GENERAL PHYSICS II (3-2). Similar to PH 002D but laboratory is included. TEXT: Smith and Cooper, *Elements of Physics*. PREREQUISITE: PH 007D.

PH 009D GENERAL PHYSICS III (3-2). Similar to PH 003D but laboratory is included. TEXT: Smith and Cooper, *Elements of Physics*. PREREQUISITE: PH 008D.

PH 010D GENERAL PHYSICS IV (3-2). Similar to PH 004D but laboratory is included. TEXT: Smith and Cooper, *Elements of Physics*. PREREQUISITE: PH 009D.

PH 011D GENERAL PHYSICS I (4-3). Mechanics. This course is designed to provide a knowledge of the principles of physics and to provide a scientific background for the study of engineering. It consists of lectures, recitations, problem sessions, and laboratory work dealing with force, motion, energy, momentum, elasticity, and hydrodynamics. TEXT: Sears and Zemansky, *University Physics*. PREREQUISITE: One term of calculus.

PH 012D GENERAL PHYSICS II (4-3). Heat, Sound, and Light. This is a continuation of General Physics I and deals with molecular mechanics, behavior of gases, thermal expansion, calorimetry, the laws of thermodynamics, wave motion, vibrating bodies, reflection and refraction of light, dispersion, interference and diffraction, and optical instruments. TEXT: Sears and Zemansky, *University Physics*. PREREQUISITE: PH 001D.

PH 013D GENERAL PHYSICS III (3-3). Electricity and magnetism. This is a continuation of General Physics I and II and deals with the fundamental principles of electrostatics, electromagnetism, electrochemistry, direct and alternating currents. TEXT: Sears and Zemansky, *University Physics*. PREREQUISITES: PH 011D and PH 012D.

PH 014D GENERAL PHYSICS IV (4-2). Modern Physics. This is a continuation of General Physics I, II and III and deals with the fundamentals of atomic and nuclear physics. Topics include: atomic and nuclear structure, optical spectra, radioactivity, nuclear processes, and particle accelerators. TEXT: Weidner and Sells, *Introductory Modern Physics*. PREREQUISITES: PH 011D, PH 012D and PH 013D.

PH 016D GENERAL PHYSICS MECHANICS (4-0). This course is a review in depth of that portion of General Physics dealing with Newtonian Mechanics and stressing quantitative use of such concepts as force, conservation of energy, conservation of momentum, rotational motion, elasticity and hydrodynamics. It is primarily for engineering science students needing physics review at this level. TEXT: Sears and Zemansky, *University Physics*. PREREQUISITES: Previous exposure to college mathematics through calculus and one course in college physics.

PH 017D GENERAL PHYSICS — THERMODYNAMICS SOUND AND LIGHT (4-0). This course is a continuation of PH 016D and is a further review in depth of General Physics, stressing the concepts of temperature, heat transfer, thermal properties of solids, liquids and gases and the laws of thermodynamics. The propagation of waves in various media is considered with emphasis on sound waves. In optics, the geometrical optics of mirrors, lenses and optical instruments will be considered; and in physical optics interference and diffraction will be stressed. TEXT: Sears and Zemansky, *University Physics*. PREREQUISITE: PH 016D.

PH 018D GENERAL PHYSICS — ELECTRICITY AND MAGNETISM (4-0). This course is a study of the concepts of electrostatics stressing Gauss' Law and the theory of electric fields and potentials. Attention will also be given to direct the alternating current flow, electromagnetic phenomena and ferromagnetism. TEXT: Sears and Zemansky, *University Physics*. PREREQUISITES: Successful completion of PH 016D and PH 017D.

PH 019C MODERN PHYSICS (4-0). This is a final course of a four-term sequence and consists of a moderately rigorous study of some of the most fundamental concepts of atomic and nuclear physics. Topics included are atomic structure, radiation from atoms, nuclear structure and nuclear processes. TEXT: Weidner and Sells, *Introductory Modern Physics*. PREREQUISITES: Successful completion of PH 016D, PH 017D, and PH 018D.

PH 021C MECHANICS (4-0). This course is a review and extension of the Mechanics portion of General College Physics. Emphasis is placed on a study in depth of the important concepts of physical mechanics. Representative topics are Newton's Laws of Motion, Conservation of Energy, Conservation of Momentum, Rotational Motion and Simple Harmonic Motion. TEXT: Halliday and Resnick, *Physics for Students of Science and Engineering*. PREREQUISITE: 8 to 10 semester hours of College Physics and 8 to 10 hours of Calculus, with acceptable grades, or demonstrated aptitude in Science and Mathematics.

PH 022C FLUID MECHANICS WAVE MOTION AND THERMODYNAMICS (4-0). This course is a continuation of PH 021C. The emphasis will be on developing a thorough understanding of the important concepts of physics which are normally catalogued under the title of this course. The

relationship of Wave Motion and Acoustics will be stressed as will the laws of Thermodynamics. TEXT: Halliday and Resnick, *Physics for Students of Science and Engineering.* PREREQUISITE: Successful completion of PH 021C.

PH 023C ELECTRICITY AND MAGNETISM (4-0). This course is a continuation of PH 021C and PH 022C. A careful study will be made of the concepts of electrostatics, Electric Fields and Gauss' Law, Electrical Potential, Magnetic Effects of Currents, Electromagnetism and the Phenomena of Ferromagnetism. DC and AC electric currents will be studied. TEXT: Resnick and Halliday, *Physics for Students of Science and Engineering.* PREREQUISITE: Successful completion of PH 021C.

PH 024C ELECTROMAGNETIC RADIATION AND OPTICS (4-0). This course is a continuation of PH 021C, PH 022C and PH 023C and gives the student a better understanding of the electrical and magnetic character of radiation. Maxwell's Laws will be studied. In Optics, maximum attention will be given to understanding interference and diffraction. Polarization of Radiation will also be studied. TEXT: Resnick and Halliday, *Physics for Students of Science and Engineering.* PREREQUISITES: Successful completion of PH 021C and PH 023C.

PH 025C MODERN PHYSICS (4-0). This is the concluding course in a sequence of courses designed to provide the student with a substantial understanding of some of the most important and basic concepts of physics. Several topics classified as "modern physics" will be studied in depth. Among these are atomic structure, radiation from atomic systems, nuclear structure, nuclear processes and the tools of modern physics experimentation. TEXT: Wiedner and Sells, *Introductory Modern Physics.* PREREQUISITES: Successful completion of PH 021C, PH 022C, PH 023C, and PH 024C.

PH 031C MECHANICS II (4-0). A continuation of PH 151C for students who are not candidates for a Master's Degree. Review of elements of dynamics, motion of a system of particles, rigid body motion in a plane, motion in a central force field. TEXTS: Resnick and Halliday, *Physics for Students of Science and Engineering;* Becker, *Introduction to Theoretical Mechanics.* PREREQUISITE: PH 151C.

PH 105C MECHANICS (4-0). The first term in a sequence of fundamental physics for students in Electrical Engineering and Electronics. The sequence includes PH 105C, PH 205C, and either PH 604C or PH 605B and PH 705B. The subject matter in the first term includes: kinematics, dynamics of a particle, energy, momentum, rotational motion, orbital motion, oscillations and wave motion. TEXT: Resnick and Halliday, *Physics for Students of Science and Engineering,* Vol. I.

PH 141B ANALYTICAL MECHANICS (4-0). Kinematics and dynamics of a particle, moving reference systems, central forces and celestial mechanics. TEXT: Fowles, *Analytical Mechanics.* PREREQUISITES: At least 8 semester hours of College Physics and 8 semester hours of Calculus; Ma 182C (may be taken concurrently).

PH 142B ANALYTICAL MECHANICS (4-0). Dynamics of a system of particles, rigid bodies, Lagrange's equations and the Hamiltonian theory of vibrations. TEXT: Fowles, *Analytical Mechanics.* PREREQUISITES: Ma 183B (may be taken concurrently) and PH 141B.

PH 151C MECHANICS I (4-1). Brief review of elementary mechanics. Motion of a particle in the dimension with emphasis on oscillatory motion. Statics of a particle. Motion of a particle in two and three dimensions with emphasis on projectile trajectories and motion in a central force field. The laboratory periods will be devoted to demonstrations and problem solving. TEXTS: Resnick and Halliday, *Physics for Students of Science and Engineering, Part I;* Symon, *Mechanics,* 2nd ed. PREREQUISITES: A previous college course in General Physics, Calculus, Vector Algebra, and Ordinary Differential Equations (the latter may be taken concurrently).

PH 152B MECHANICS II (4-0). A continuation of PH 151C. Motion of a system of particles, including the conservation laws, center of mass, and collision problems. Coupled harmonic oscillators. Rotation of a rigid body about an axis. Motion of a pendulum. Statics of rigid bodies. Stress and strain. Rotating coordinate systems. The vibrating string and wave propagation along a string. TEXTS: Resnick and Halliday, *Physics for Students of Science and Engineering, Part II;* Symon, *Mechanics,* 2nd ed. PREREQUISITE: PH 151C.

PH 153A MECHANICS III (4-0). A continuation of PH 152B. Topics selected from: mechanics of continuous media; gravitational theory; Lagrange's equations; Hamilton's equations; tensor algebra and the rotation of a rigid body in three dimensions; theory of small vibrations; perturbation theory. TEXT: Symon, *Mechanics,* 2nd ed. PREREQUISITE: PH 152B.

PH 154A SPACE AND MISSILE MECHANICS (4-0). The solar system. Missile and satellite trajectories including intercept problems and perturbations. Equations of motion of a missile including yawing, swerving, drag, and angular motion. Stability considerations. TEXT: Instructor's notes. PREREQUISITE: PH 153A.

PH 155A ADVANCED MECHANICS I (3-0). Review of elementary principles, Lagrange formulations with applications. Hamilton's principle with applications to non-conservative and non-holomonic systems. The two body central force problem. Kinematics of rigid body motion. Orthogonal transformation. Formal properties of transformation matrix. Infinitesimal rotation. Coriolis force. Rigid body motion, the inertia tensor, Euler's equation, the symmetrical top. TEXT: Goldstein, *Classical Mechanics.* PREREQUISITES: PH 142B or PH 153A, PH 365C (may be taken concurrently).

PH 156A ADVANCED MECHANICS II (3-0). Special relativity in classical mechanics, including Lorentz transformation and Lagrange formulation. Hamilton's equations of motion. Canonical transformations. Hamilton-Jacobi equation. Small oscillations, classical perturbation theory. TEXT:

Goldstein, *Classical Mechanics.* PREREQUISITE: PH 155A.

PH 161A FLUID MECHANICS (3-0). The fundamental concepts of fluid mechanics from the continuum and kinetic theory points of view; development and interpretation of the equation of continuity, the Navier-Stokes equation, the equation of state. TEXT: Landau and Lifshitz, *Fluid Mechanics* and instructor's notes. PREREQUISITES: PH 541B, Ma 260C and Ma 245B or equivalents.

PH 162A ADVANCED HYDRODYNAMICS (3-0). Solutions to the equations of fluid dynamics; potential flow, exact solutions of the Navier-Stokes equation, laminar and turbulent boundary layers, transitions, non-steady flow, hydrodynamic noise. TEXTS: Landau and Lifshitz, *Fluid Mechanics*, Schlichting, *Boundary Layer Theory*. PREREQUISITE: PH 161A.

PH 190D SURVEY OF PHYSICS I (3-0). Elementary concepts and laws of statics and dynamics. Introduction to the statics and dynamics of fluids. Temperature, heat, radiation, kinetic theory and the gas laws. Fundamentals of vector representation and notation. TEXT: Smith and Cooper, *Elements of Physics.*

PH 191D SURVEY OF PHYSICS II (3-0). A continuation of PH 190D. A survey of wave propagation, sound, electricity and magnetism, atomic structure, the properties of light, and other electromagnetic wave phenomena. TEXT: Smith and Cooper, *Elements of Physics.* PREREQUISITE: PH 190D or equivalent.

PH 192D SURVEY OF PHYSICS III (3-0). A continuation of PH 191D. Survey of physical optics. Introduction to atomic structure including kinetic theory. TEXT: Smith and Cooper, *Elements of Physics.* PREREQUISITE: PH 191D or equivalent.

PH 196C REVIEW OF GENERAL PHYSICS (4-2). Principles of statics and dynamics, oscillatory motion, wave motion fields, electricity and magnetism. TEXT: Resnick and Halliday, *Physics for Students of Engineering and Science.* PREREQUISITES: Ma 230D and Ma 120C or equivalent.

PH 205C WAVES AND PARTICLES (4-0). Follows PH 105C. The properties of waves, propagation, Doppler effect, waves in three dimensions, reflection, refraction, interference and diffraction, polarization, wave-particle duality, photons, electron waves, phonons, indeterminancy principle, Bohr model of the atom and its defects. TEXT: Halliday and Resnick, *Physics for Students of Science and Engineering*, Vol. II. PREREQUISITE: PH 105C.

PH 240C OPTICS AND SPECTRA (3-3). Reflection and refraction of light, optical systems, dispersion, interference, diffraction, poralization. Basic atomic structure, photoelectric effect, radiation from atoms, molecules and solids. TEXTS: Sears, *Optics;* Jenkins and White, *Fundamentals of Optics.*

PH 241C RADIATION (3-3). Fundamentals of geometric and physical optics. Wave phenomena and wave propagation. Origin of the quantum theory, photoelectric effect, radiation from atoms, molecules and solids, target detection by optical and infrared devices. TEXTS: Sears, *Optics;* Jenkins and White, *Fundamentals of Optics.*

PH 242C RADIATION (3-0). Fundamentals of geometric and physical optics. Wave phenomena and wave propagation. Particles and waves. Radiation from atoms, molecules, and solids. Sensors used for target detection. TEXTS: Sears, *Optics;* Jenkins and White, *Fundamentals of Optics.*

PH 260C PHYSICAL OPTICS (3-2). Reflection and refraction of light, optical systems, dispersion, interference, diffraction, polarization. Basic atomic structure, photoelectric effect, radiation from atoms, molecules and solids. TEXTS: Sears, *Optics;* Jenkins and White, *Fundamentals of Optics.*

PH 265C PHYSICAL OPTICS (4-2). Elementary geometrical optics. Wave phenomena and wave propagation, interference and diffraction, polarization. Properties of light sources. TEXTS: Sears, *Optics;* Jenkins and White, *Fundamentals of Optics.*

PH 270B PHYSICAL OPTICS (4-2). Review of geometrical optics. Wave phenomena and wave propagation, interference, diffraction, polarization, double refraction, dispersion. TEXT: Jenkins and White, *Fundamentals of Optics.*

PH 350B SPECIAL TOPICS IN ELECTROMAGNETISM (4-0). Development and applications of Maxwell's Equations for selected students. TEXTS: Whitmer, *Electromagnetics;* Kraus, *Electromagnetics.* PREREQUISITE: Consent of Instructor.

PH 360B ELECTRICITY AND MAGNETISM (4-0). Electrostatics. Electric currents. The magnetic field, Maxwell's equations. Plane waves, reflection radiation. TEXT: Skilling, *Fundamentals of Electric Waves.* PREREQUISITES: PH 241C, PH 141B.

PH 365C ELECTRICITY AND MAGNETISM (4-1). Electrostatics. Dielectric media. Direct currents. Magnetostatics. Induced emf. Magnetic media. Maxwell's equations. The laboratory periods will be devoted to demonstrations and problem solving. TEXT: Schwarz, *Intermediate Electromagnetic Theory.* PREREQUISITE: PH 701C or equivalent.

PH 366B ELECTROMAGNETISM (4-0). A continuation of PH 365C. Applications of Maxwell's equations: plane waves in unbounded media; refraction and reflection of plane waves; transmission lines; wave guides; introduction to relativity. TEXT: Schwarz, *Intermediate Electromagnetic Theory.* PREREQUISITE: PH 365C.

PH 367A ADVANCED ELECTROMAGNETISM I (4-0). Solutions to Laplace's and Poisson's equations. Applications of Hertz potential or vector potential to radiation

problems. Scattering and dispersion. TEXT: Jackson, *Classical Electrodynamics.* PREREQUISITE: PH 366B.

PH 368A ADVANCED ELECTROMAGNETISM II (3-0). Tensors in special relativity. Relativistic classical electromagnetic field theory. The Lienard-Wiechert potentials. Lorentz electron theory. TEXTS: Landau and Lifshitz, *Classical Theory of Fields;* Barut, *Electrodynamics and Classical Theory of Fields and Particles.* PREREQUISITES: PH 367A and PH 155A.

PH 424B FUNDAMENTAL ACOUSTICS (4-0). This course is designed to provide a background in vibration and sound for students of operations analysis. An analytical study of the dynamics of free, forced and damped simple harmonic oscillators, strings, bars and membranes. Development of, and solutions to, the acoustic wave equation. Propagation of plane waves in fluids and between different media. Acoustic filters. Beam patterns and directivity of acoustic radiation from a piston. Radiation reaction. Transducers for underwater sound. TEXT: Kinsler and Frey, *Fundamentals of Acoustics.* PREREQUISITES: Ma 182C and PH 141B.

PH 425B UNDERWATER ACOUSTICS (3-2). A continuation of PH 424B for students of operations analysis. An analytical survey of the propagation of underwater acoustic waves as influenced by boundary conditions, refraction, scattering, and attenuation. Physical characteristics of sonar transducers. Sonar systems and developments. Experiments in underwater acoustics and noise analysis. TEXTS: Kinsler and Frey, *Fundamentals of Acoustics;* NDRC Technical Summary, *Principles of Underwater Sound;* NDRC Technical Summary, *Physics of Sound in the Sea.* PREREQUISITE: PH 424B.

PH 431B FUNDAMENTAL ACOUSTICS (4-0). This course is designed to provide a background in vibration and sound for students of electronics or ordnance. An analytical study of the dynamics of free, forced, and damped simple harmonic oscillators, strings, bars, and membranes. Development of, and solutions to, the acoustic wave equation. Propagation of plane waves in fluids and between media. Acoustic filters. Beam patterns and directivity of acoustic radiation from a piston, radiation reaction. Loudspeakers and microphones. TEXT: Kinsler and Frey, *Fundamentals of Acoustics.* PREREQUISITES: MA 113B and PH 105C, PH 151C.

PH 432B UNDERWATER ACOUSTICS (4-3). A continuation of PH 431B for students of electronics or ordnance. Transmission of sound in the ocean, including problems of refraction, attenuation, scattering, reverberation, and channel propagation. Physical principles used in sonar systems. Experiments in acoustical measurements, transducer measurements and noise analysis. TEXTS: Kinsler and Frey, *Fundamentals of Acoustics;* NDRC Technical Summary—*Principles of Underwater Sound;* and NDRC Technical Summary—*Physics of Sound in the Sea.* PREREQUISITE: PH 431B.

PH 433A PROPAGATION OF WAVES IN FLUIDS (3-0). A theoretical treatment of the propagation of sound in fluids including molecular relaxation effects and both ray and wave propagation characteristics in bounded, inhomogeneous media. TEXTS: Lindsay, *Mechanical Radiation;* Officer, *Introduction to the Theory of Sound Transmission.* PREREQUISITE: PH 432B.

PH 441B SHOCK WAVES IN FLUIDS (4-0). Hydrodynamic equations. Propagation of acoustic waves in fluids. Shock waves propagated from nuclear explosions; Rankine-Hugoniot equations for the shock front, scaling laws, experimental measurements. TEXTS: Kinsler and Frey, *Fundamentals of Acoustics;* Cole, *Underwater Explosions.* PREREQUISITES: Ma 183B and PH 152B, or equivalents.

PH 442A FINITE AMPLITUDE WAVES IN FLUIDS (3-0). Non-linear effects of intense sounds. Theory of propagation of shock waves in fluids. TEXTS: Cole, *Underwater Explosions;* Lindsay, *Mechanical Radiation;* and Landau and Lifshitz, *Fluid Mechanics.* PREREQUISITE: PH 432B or equivalent.

PH 450C UNDERWATER ACOUSTICS (3-2). A survey of the fundamentals of acoustics, with particular emphasis on the radiation, transmission and detection of sound in the sea. TEXTS: Kinsler and Frey, *Fundamentals of Acoustics;* NDRC Technical Summary—*Principles of Underwater Sound;* NDRC Technical Summary—*Physics of Sound in the Sea.* PREREQUISITE: Ma 073C or Ma 244C or equivalent.

PH 461A TRANSDUCER THEORY AND DESIGN (3-3). A theoretical treatment of the fundamental phenomena in the design of crystal, magneto-strictive, and ceramic sonar transducers. Characteristics and parameters of various sonar transducer systems are studied in the Laboratory. TEXTS: Hueter and Bolt, *Sonics;* NDRC Technical Summary, *Magnetostriction Transducers;* Kinsler and Frey, *Fundamentals of Acoustics.* PREREQUISITE: PH 432B or equivalent.

PH 471A ACOUSTICS RESEARCH (0-3). Advanced laboratory projects in acoustics. PREREQUISITE: PH 432B or equivalent.

PH 480E ACOUSTICS COLLOQUIUM (0-1). Reports on current research and study of recent research literature in conjunction with the student thesis. PREREQUISITE: PH 432B or equivalent.

PH 530C THERMODYNAMICS (3-0). Fundamental theory of thermodynamics and applications to physical problems. First and second laws of thermodynamics, equations of state, phase changes, thermodynamic potentials. TEXT: Sears, *Thermodynamics.* PREREQUISITES: Calculus of Several Variables, Introduction to Mechanics.

PH 531A ADVANCED THERMODYNAMICS (3-0). Principles of classical thermodynamics. Extremum principles and thermodynamic stability. Applications to gases,

solids, and to electric and magnetic systems. Introduction to fluctuations and irreversible thermodynamics. TEXT: Callen, *Thermodynamics.* PREREQUISITES: PH 153A or PH 155A, PH 366B, PH 636B or PH 671B, PH 530C or equivalent.

PH 541B INTRODUCTORY STATISTICAL PHYSICS (4-0). Distribution functions, kinetic theory, introduction to classical and quantum statistics. Applications to gases, solids, and radiation. TEXTS: Sears, *Thermodynamics;* Andrews, *Equilibrium Statistical Mechanics.* PREREQUISITES: PH 152B, PH 530C, Ordinary Differential Equations.

PH 545A STATISTICAL PHYSICS I (3-0). Kinetic theory and the Boltzmann theorem; configuration and phase space; the Lionville Theorem; ensemble theory: microcanonical, canonical, and grand canonical ensembles; quantum statistics. TEXT: Huang, *Statistical Mechanics.* PREREQUISITES: PH 153A or PH 156A, PH 636B or PH 671B, PH 541B, and PH 366B.

PH 546A STATISTICAL PHYSICS II (3-0). A continuation of PH 545A with selected applications to molecules, Bose-Einstein gases, Fermi-Dirac liquids and superconductivity. TEXT: Huang, *Statistical Mechanics.* PREREQUISITE: PH 545A.

PH 600D NUCLEONICS FUNDAMENTALS (3-0). A study of atomic structure, natural and artificial radioactivity, nuclear structure, nuclear fission, and chain reaction. Introduction to reactor principles, reactor components, and nuclear power plants. USUAL BASIC FOR EXEMPTION: Equivalent educational background. TEXTS: Hoisington, *Nucleonics Fundamentals* and NAVPERS 10786, *Basic Nuclear Physics.*

PH 604C STRUCTURE OF ATOMS AND SOLIDS (4-0). Follows PH 205C for those students not planning to take PH 705B. Kinetic theory of gases, fundamental particles, brief treatment of nuclear physics, special relativity, the general principles of quantum mechanics, periodic chart of the elements, vector model of the atom, electrons in solids, semi-conductors and semi-conducting devices. TEXTS: Weidner and Sells, *Elementary Modern Physics;* Sproull, *Modern Physics,* 2nd ed.; Resnick and Halliday, *Physics for Students of Science and Engineering,* Vols. I and II. PREREQUISITE: PH 205C.

PH 605B ATOMIC PHYSICS (4-0). Follows PH 205C for those students planning to take PH 705B. Kinetic theory of gases, Boltzmann function, fundamental particles, introduction to nuclear physics, special relativity, quantum mechanics, free and bound particles, emission and absorption of radiation, the one-electron atom, periodic table of the elements, many-electron atoms, electron spin, X-rays, vibration-rotation spectra for molecules masers and lasers. TEXTS: Sproull, *Modern Physics,* 2nd ed.; Weidner and Sells, *Elementary Modern Physics;* Resnick and Halliday, *Physics for Students of Sciences and Engineering,* Vols. I and II. PREREQUISITE: PH 205C.

PH 620B ELEMENTARY ATOMIC PHYSICS (4-0). Fundamental particles, forces on particles, kinetic theory, photons as waves and particles, electrons as particles and waves, elementary quantum physics, binding energies in atoms and nuclei. Atomic structure and spectra, X-rays, molecular structure, atoms in solids. TEXT: Weidner and Sells, *Elementary Modern Physics.* PREREQUISITE: PH 141B or equivalent.

PH 621B ELEMENTARY NUCLEAR PHYSICS (4-0). A descriptive and phenomenological course including properties of nucleons, nuclear structure, radioactivity, nuclear reactions, fission, and fusion. TEXT: Kaplan, *Nuclear Physics.* PREREQUISITE: PH 620B or PH 630B.

PH 622B NUCLEAR PHYSICS LABORATORY (0-3). Discussions and experiments on the interaction of nuclear radiations with matter and detection techniques. PREREQUISITE: PH 621B (may be taken concurrently).

PH 630B ELEMENTARY ATOMIC PHYSICS (4-0). Elementary particles, interaction of particles, photoelectric effect, electron diffraction, the nuclear atom. Bohr model of the atom, energy levels in atoms, optical and X-ray spectra, Pauli exclusion principle. Zeeman effect, Schroedinger's equation. TEXT: Weidner and Sells, *Elementary Modern Physics.* PREREQUISITES: PH 152B and PH 240C or equivalents.

PH 631B ATOMIC PHYSICS LABORATORY (0-3). Quantitative laboratory exercises in atomic physics. PREREQUISITE: PH 620B or PH 630B (must be taken concurrently).

PH 635B ATOMIC PHYSICS I (5-0). Special theory of relativity. Fundamental particles, interactions of particles, photoelectric effect, wave-particle duality, Rutherford scattering, elementary quantum mechanics, Schroedinger equation, quantum mechanical operators, Bohr theory of the atom, quantum mechanical solution for the hydrogen atom, vector model of the atom, quantum numbers, Pauli exclusion principle, periodic table of the elements. TEXTS: Richtmyer, Kennard and Lauritsen, *Modern Physics,* and Sproull, *Modern Physics.* PREREQUISITES: Ma 230D and PH 240C.

PH 636B ATOMIC PHYSICS II (4-3). Fine structures in the hydrogen atom, Zeeman effect, selection rules in atomic spectra, X-rays, binding energies in molecules, molecular structure, band theory of solids, seminconductors, electron and nuclear spin resonance. Laboratory: Quantitative experiments related to the lecture material of PH 635B and PH 636B. TEXTS: Richtmyer, Kennard and Lauritsen, *Modern Physics;* Sproull, *Modern Physics.* PREREQUISITE: PH 635B.

PH 637B NUCLEAR PHYSICS I (3-0). Basic nuclear concepts; mass, binding energy and stability; radioactivity and decay law; passage of charged particles and photons through matter. TEXTS: Segré, *Nuclei and Particles;* Kap-

lan, *Nuclear Physics;* others as required by instructor. PREREQUISITES: PH 365C, PH 636B or PH 671B.

PH 638B NUCLEAR PHYSICS II (3-3). Further nuclear properties; electric and magnetic moments; nuclear models; nuclear reactions; fission; theories of alpha-, beta-, and gamma-decay. Laboratory: experiments on the interactions of nuclear radiations with matter; statistics of decay; detection techniques. TEXTS: Segré, *Nuclei and Particles;* Kaplan, *Nuclear Physics;* Valente, *A Manual on Experiments in Reactor Physics.* PREREQUISITE: PH 637B.

PH 639A NUCLEAR PHYSICS II (4-3). Quantitative treatment of nuclear moments and angular momentum; models; partial wave analysis of reactions; the deuteron; quantum mechanical treatment of radioactive decay processes; nuclear fission and reactors. Laboratory: Same as PH 638B. TEXTS: Same as PH 638B. PREREQUISITE: PH 637B.

PH 646A ADVANCED NUCLEAR PHYSICS I (3-0). Partial wave analysis of scattering, the theories of nuclear reactions, nuclear forces. TEXTS: Blatt and Weisskopf, *Theoretical Nuclear Physics;* Sachs, *Nuclear Theory;* Bethe and Morrison, *Elementary Nuclear Theory;* the periodicals of nuclear physics. PREREQUISITES: PH 639A, PH 367A, and PH 712A.

PH 647A ADVANCED NUCLEAR PHYSICS II (3-0). Nuclear models, theory and beta-decay, theory of gamma emission, theory of alpha-decay. TEXTS: Blatt and Weisskopf, *Theoretical Nuclear Physics;* Sachs, *Nuclear Theory;* Bethe and Morrison, *Elementary Nuclear Theory;* the periodicals of nuclear physics. PREREQUISITE: PH 646A.

PH 648A HIGH ENERGY PHYSICS (3-0). Introduction to techniques and theories. Topics selected from scattering, relativistic particle dynamics, nuclear reactions, elementary particles, and accelerators and other experimental equipment. TEXTS: Jackson, *Physics of Elementary Particles;* Ritson, *Techniques of High Energy Physics.* PREREQUISITES: PH 636B or 671B, PH 638B, PH 711A.

PH 650B PHYSICS OF ELECTRICAL DISCHARGES. IN GASES (4-0). A course covering the fundamental processes occurring in electrical discharge in gases. Emission of electrons from surfaces, excitation, ionization, recombination, deexcitation of atoms and molecules. Mobility and diffusion, electrical breakdown in gases. Glow and arc discharges, sheaths, experimental methods. TEXTS: Cobine, *Gaseous Conductors;* Von Engel, *Ionized Gases;* Francis, *Ionization Phenomena in Gases.* PREREQUISITES: PH 630B or PH 635B.

PH 651A REACTOR THEORY I (3-0). Nuclear fission, the diffusion and slowing down of neutrons, homogeneous thermal reactors. TEXTS: Glasstone and Edlund, *The Elements of Nuclear Reactor Theory;* Murray, *Nuclear Reactor Physics.* PREREQUISITES: PH 638B and Ma 113B or equivalent.

PH 652A REACTOR THEORY II (3-0). A continuation of PH 651A. Time behavior, reactor control, reflected systems, multigroup theory, heterogeneous systems, perturbation theory. TEXTS: Glasstone and Edlund, *The Elements of Nuclear Reactor Theory;* Murray, *Nuclear Reactor Theory.* PREREQUISITE: PH 651A.

PH 653A REACTOR PHYSICS LABORATORY (0-2). Experiments using the AGN-201 reactor including the measurement of the basic reactor parameters and the study of its transient behavior. TEXTS: Aerojet-General, *Elementary Reactor Experimentation;* Hughes, *Pile Neutron Research;* Glasstone and Edlund, *The Elements of Nuclear Reactor Theory.* PREREQUISITES: PH 651A and PH 652A. (The latter may be taken concurrently.)

PH 654A PLASMA PHYSICS I (4-0). Introduction to physical and mathematical concepts fundamental to various branches of plasma physics such as ionispheric communications, ion propulsion, plasma amplifiers and controlled fusion. Hydromagnetic and Boltzmann equations. Behavior of charged particles in electric and magnetic fields. Interaction of electromagnetic waves with plasmas. Magnetic pressure. Debye length. TEXTS: Uman, *Introduction to Plasma Physics;* Rose and Clark, *Plasma and Controlled Fusion;* Glasstone and Loveberg, *Controlled Thermonuclear Reactions.* PREREQUISITES: PH 367A, PH 541B, and PH 636B or PH 671B.

PH 655A PLASMA PHYSICS II (4-0). A continuation of Plasma Physics I. Collisions of plasma particles, relaxation times. Bremmstrahlung and cyclotron radiation. Longitudinal oscillations of electrons and ions. Hydromagnetic waves in plasmas. Transport theory using the Boltzmann equation. Pinch effect, plasma instabilities. TEXTS: Same as PH 654A. PREREQUISITE: PH 654A.

PH 656A ADVANCED PLASMA THEORY (3-0). Topics covered will be related to research problems in progress or contemplated and will depend somewhat on the interests of the students enrolled. Possible topics are: diffusion in plasmas, radiation from plasmas and the propagation of hydromagnetic waves in plasmas. Use will be made of the current scientific literature. TEXTS: Allis, Buchsbaum and Bers, *Waves in Anisotropic Plasmas;* Lecture Notes. PREREQUISITE: PH 655A.

PH 670B ATOMIC PHYSICS I (3-0). Fundamental particles, kinetic theory, forces on particles, special theory of relativity, wave-particles duality, quantum mechanics of simple systems, quantum mechanical operators, Bohr model of the atom, quantum mechanical solution for the hydrogen atom. TEXTS: Richmyer, Kennard and Lauritsen, *Modern Physics;* Eisberg, *Fundamentals of Modern Physics;* Lecture Notes. PREREQUISITES: PH 152B or equivalent. Ma 240C or equivalent, and PH 270B.

PH 671B ATOMIC PHYSICS II (3-3). Fine structure in the hydrogen atom, vector model of the atom, spectroscopic notation, Zeeman effect, many-electron atoms, periodic table in terms of quantum numbers, X-rays, binding in molecules.

Laboratory: Quantitative experiments related to lecture material of PH 670B and PH 671B. TEXTS. Richmyer, Kennard and Lauritsen, *Modern Physics;* Eisberg, *Fundamentals of Modern Physics;* Lecture Notes. PREREQUISITE: PH 670B.

PH 675A ATOMIC COLLISION PROCESSES (3-0). Atomic interactions of interest in low density gases. Classical and quantum description of the collision process. Selected applications from the physics of the upper atmosphere, effects of solar radiation on atmospheric and interplanetary gases. Discussion of pertinent experimental techniques. TEXT: McDaniels, *Collision Phenomena in Ionized Gases.* PREREQUISITES: PH 636B or PH 671B, or consent of instructor.

PH 701C INTRODUCTION TO THE METHODS OF THEORETICAL PHYSICS (4-0). An introduction to the techniques used in solving problems in the classical field theories. Vector and scalar fields are studied. Solutions to the source-free equations most often encountered in physics are discussed. TEXT: To be chosen by instructor. PREREQUISITES: Calculus of Several Variables, Algebra of Complex Numbers, Vector Algebra, and Ordinary Differential Equations (the latter may be taken concurrently).

PH 705B SOLID STATE PHYSICS (4-2). Follows PH 605B. Crystals and lattice properties, specific heat, thermal conductivity, phonons, properties of electrons in solids, Fermi-Dirac distribution, band theory, Brillouin zones, effective mass, negative mass, holes, electrical conductivity, Hall effect, intrinsic and impurity semi-conductors, virtual Fermi energy, photoconductivity, fluorescence, lasers, diodes, tunnel diodes, solar calls, thermo-electric power and cooling, transistors, magnetic properties of solids, masers, dielectrics and ferroelectrics, superconductivity and applications, brief treatment of plastic and mechanical properties. Laboratory experiments in selected areas of solids. TEXTS: Kittel, *Elementary Solid State Physics.* 1962 ed.; Sproull, *Modern Physics.* 2nd ed.; Weidner and Sells, *Elementary Modern Physics;* Resnick and Halliday, *Physics for Students of Science and Engineering,* Vols. I and II. PREREQUISITE: PH 605B.

PH 711A QUANTUM MECHANICS I (3-0). The need for quantum theory. Matrix formulation of quantum mechanics. The square well potential and the harmonic oscillator. TEXTS: Dirac, *Quantum Mechanics;* Schiff, *Quantum Mechanics.* PREREQUISITES: PH 156A, PH 366B, PH 636B or PH 671B.

PH 712A QUANTUM MECHANICS II (3-0). The hydrogen atom. Time independent and time dependent perturbation theory. Identical particles and spin. TEXTS: Dirac, *Quantum Mechanics;* Schiff, *Quantum Mechanics.* PREREQUISITE: PH 711A.

PH 713A QUANTUM MECHANICS III (3-0). Atoms, relativistic particle wave equations and solutions. TEXTS: Schiff, *Quantum Mechanics;* Bjorken and Drell, *Relativistic Quantum Mechanics.* PREREQUISITE: PH 712A.

PH 714A QUANTUM FIELD THEORY I (3-0). Quantization of scalar, spinor, and vector fields. Interacting fields. TEXT: Schweber, *Introduction to Relativistic Quantum Field Theory.* PREREQUISITE: PH 713A.

PH 715A QUANTUM FIELD THEORY II (3-0). The S-matrix and renormalization. Strong, electromagnetic, and weak interactions. Introduction to dispersion relations. TEXT: Schweber, *Introduction to Relativistic Quantum Field Theory.* PREREQUISITE: PH 714A.

PH 718A PHYSICAL GROUP THEORY (3-0). Invariance of quantum mechanical systems to certain groups of transformations. Topics to be selected from finite rotation groups and crystal symmetries, the continuous rotation group in three dimensions, transformation groups associated with elementary particle symmetries. PREREQUISITE: PH 712A.

PH 719A RELATIVITY AND COSMOLOGY (3-0). Foundations of the special theory of relativity, tensor calculus, introduction to the general theory of relativity. Experimental tests of the general theory. Introduction to cosmology. TEXTS: Eddington, *The Mathematical Theory of Relativity;* Bondi, *Cosmology.* PREREQUISITES: PH 636B or PH 671B, Ma 260C.

PH 723B THEORY OF SOLID STATE AND QUANTUM DEVICES (4-0). Theory of the structure of solids with emphasis on the electronic structure. Topics in quantum mechanics with special emphasis on quantum behavior as applied to quantum electronic devices: stimulated emission, spin resonance, rotating coordinate, relaxation times. Applications to masers, lasers, parametric amplifiers, magnetic instruments, extreme constant frequency oscillators, etc. TEXTS: Decker, *Introduction to Solids;* Herzberg, *Atomic Spectra;* Singer, *Masers.* PREREQUISITE: PH 630B.

PH 724A THEORY OF QUANTUM ELECTRONIC DEVICES (4-0). Theory of the operation of electronic devices depending on energy states and the quantum nature of radiation; topics in quantum mechanics, spin resonance, rotating coordinates, relaxation times, internal fields; application to specific electronic devices such as masers, microwave and optical pumping devices, paramagnetic amplifiers, magnetic instruments. TEXTS: Herzberg, *Atomic Spectra;* Townes, *Microwave Spectroscopy.* PREREQUISITE: PH 620B or equivalent.

PH 725A PHYSICS OF SOLIDS I (4-0). Theory of the structure and properties of solids; crystal symmetry and the anisotropy of physical properties, binding energy, lattice specific heat, thermal conductivity, properties of phonons. TEXTS: Wannier, *Solid State Theory;* Kittel, *Introduction to Solid State Physics.* PREREQUISITES: PH 635B, PH 636B.

PH 726A PHYSICS OF SOLIDS II (4-2). A continuation of PH 725A, with laboratory experiments relating to both terms. Electronic properties of solids, band theory, effective electron mass, Brillouin zones, semiconductors, and solid

state electronic devices, magnetic properties, spin resonance, dielectrics, superconductivity, imperfections in solids and the related mechanical properties. TEXTS: Wannier, *Solid State Theory;* Kittel, *Introduction to Solid State Physics.* PREREQUISITE: PH 725A.

PH 730A PHYSICS OF THE SOLID STATE (4-2). Fundamental theory and related laboratory experiments dealing with solids, with emphasis on electronic properties; crystals, binding energy, anisotropy, lattice oscillations, hand theory of electrons, Brillouin zones, "hole" concept, effective mass, electrical conductivity, insulators and semiconductors, fluorescence, junction rectifiers, transistors, magnetism, and dielectrics. TEXTS: Dekker, *Solid State Physics;* Kittel, *Introduction to Solid State Physics.* PREREQUISITES: PH 636B or PH 671B.

PH 731A ADAVNCED SOLID STATE PHYSICS I (3-0). Fundamental studies of selected topics in solid state physics. The material selected will be chosen from: Theory of specific heats, transport properties, one electron approximations, the cohesive energy, mechanical properties, optical properties, magnetic properties, and resonance methods. TEXTS: Kittel, *Introduction to Solid State Physics;* Seitz, *Modern Theory of Solids;* Seitz and Turnbull, *Solid State Physics;* and current literature. PREREQUISITES: PH 730A and PH 711A.

PH 732A ADVANCED SOLID STATE PHYSICS II (3-0). A continuation of PH 731A with emphasis on the study of the current scientific literature. PREREQUISITE: PH 731A.

PH 750E PHYSICS COLLOQUIUM (0-1). Discussion of topics of current interest in the field of physics and student thesis reports.

PH 770A READING IN ADVANCED PHYSICS (3-0). Supervised reading from the periodicals in fields of advanced physics selected to meet the needs of the student.

Root Hall

Spanagel Hall

POSTGRADUATE SCHOOL STATISTICS

GRADUATES BY YEARS

	1946-1950	1951-1955	1956-1960	1961	1962	1963	1964	Total
Bachelor of Arts	.....	.....	.....	.....	4	59	47	110
B.S. in Aeronautical Engineering	73	212	212	57	36	29	34	653
B.S. in Chemistry	.....	.....	3	.....	.....	3	.....	6
B.S. in Communications Engineering	.....	.....	42	12	13	7	30	104
B.S. in Electrical Engineering	62	115	98	50	60	31	59	475
B.S. in Engineering Electronics	94	177	92	18	45	28	44	498
B.S. in Management	.....	.....	.....	9	3	14	27	53
B.S. in Mechanical Engineering	43	116	52	22	14	10	16	273
B.S. in Meteorology	16	104	77	25	30	16	21	289
B.S. in Physics	.....	15	36	8	21	16	16	112
Bachelor of Science	.....	56	94	103	116	115	119	603
Total Baccalaureate Degrees	288	795	706	304	342	328	413	3176
M.S. in Aeronautical Engineering	.....	.....	.....	3	4	12	7	26
M.S. in Chemistry	.....	.....	16	.....	.....	2	1	19
M.S. in Electrical Engineering	7	34	46	26	19	15	15	162
M.S. in Engineering Electronics	68	120	78	11	23	24	22	346
M.S. in Management	.....	.....	.....	74	87	89	71	321
M.S. in Management/Data Processing	.....	.....	.....	.....	.....	.....	7	7
M.S. in Mechanical Engineering	20	36	48	11	14	9	8	146
M.S. in Meteorology	23	19	40	14	14	6	10	126
M.S. in Operations Research	.....	.....	.....	.....	.....	.....	31	31
M.S. in Physics	.....	25	104	20	28	39	15	231
Master of Science	.....	17	65	16	20	25	25	168
Total Master's Degrees	118	251	397	175	209	221	212	1583
Aeronautical Engineer	.....	.....	.....	.....	.....	1	.....	1
Doctor of Philosophy	.....	.....	1	1	2	3	5	12
TOTAL DEGREES	406	1046	1104	480	553	553	630	4772

GRADUATES OF THE POSTGRADUATE SCHOOL 1964

DIPLOMAS OF COMPLETION, ENGINEERING SCIENCE

ADAMS, Jerome B., LT, USN
ADAMS, John W., LT, USN
BACKES, Ronald J., LCDR, USN
BARLOW, James D., LCDR, USN
BEAMON, Joseph E., LT, USN
BECK, John L., LCDR, USN
BECK, Liston C., Jr., LT, USN
BOGGS, Harold A., LT, USN
BOSTICK, James H., LT, USN
BORCIK, Andrew J., Jr., LT, USN
BOTKIN, Harry L., LT, USN
BRADY, Paul S., LT, USNR
BRANCH, Lyle F., LT, USN
BREAST, Jerry C., LT, USN
BREDDERMAN, Rudolph T. A., LT, USN
BRICK, John H., LCDR, USN
BROWN, Alan R., LT, USN
BROWN, James R., LCDR, USN
CARLTON, George A., LCDR, USN
CASSERI, Aldo J., LTJG, USN
CHAMBERS, John J., LCDR, USN
CHILDERS, Donald J., LCDR, USN
CIPPERLY, Robert H., LT, USNR
CLARK, James R., LCDR, USN
COLENDA, Herbert F., LCDR, USN
COSTIGAN, Robert A., LCDR, USN
COX, Edward F., LT, USN
CREW, Perry L., LT, USN
CULP, Melvin F., LTJG, USN
CUPP, Larry L., LTJG, USN
CURTIS, Wayne, LT, USN
D'AMATO, Joseph J., LT, USN
DANCER, Jerry D., LT, USN
DAVIS, Philip C., LT, USN
DAVIS, Vibert H., LTJG, USN
DEFELICE, Edward A., LCDR, USN
DIETRICH, William H., LT, USN
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DUNCAN, John D., LCDR, USN
EDWARDS, Joshua V., LT, USN
EDWARDS, Leslie R., LT, USN
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GLOECKNER, Frank J., LT, USN
GOODWIN, James B., LT, USN
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HURD, DeVon H., LT, USN
IVES, David W., LT, USN
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JONES, Gordon S., LTJG, USN
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KEESLER, Byron H., LT, USN
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MASON, John A., LT, USN
MOMMSEN, Durward B., Jr., LTJG USN
MAURER, Earl T., LT, USN
MURPHY, Gilbert F., Jr., LCDR, USN
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DIPLOMAS OF COMPLETION MANAGEMENT / DATA PROCESSING

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VILLASANA, Felix E., LCDR, Venezuelan Navy

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ANCHETA, Erasmo D., LT, Republic of Philippines Navy
BEHROUZ, Houshang, LTJG, Imperial Iranian Navy
BUI-HUY, Phong, LT, Vietnamese Navy
BRANCO, Paulo Vianna Castello, CDR, Brazilian Navy
CHIEH-TSAO, Lin, LCDR, Republic of China Navy
DAGNE, Melaku, LT, Imperial Ethiopian Navy
DE, Vu Trong, LTJG, Vietnamese Navy
DEMELEW, Yeshiwas, LT, Imperial Ethiopian Navy
DEYHIMI, Siamak, LT, Imperial Iranian Navy
FERNANDEZ, Proceso C., LTJG, Republic of Philippines Navy
FIUZI, Farid, LTJG, Imperial Iranian Navy
FREIRE, Luis A., LT, Peruvian Navy
HERRERA, Hugo N., LCDR, Ecuadorian Navy
HAK, Hwang Kyu, LCDR, Republic of Korea Navy
HON, Nguyen Van, LTJG, Vietnamese Navy
JAHANBANI, Nasser, LT, Imperial Iranian Navy
JUSUF, Kosasih, LT, Indonesian Navy
KARAKA, Nowzar, LT, Imperial Iranian Navy
KARIMI, Mahmoud, LTJG, Imperial Iranian Navy
KASSAHUN, Yemane, LT, Imperial Ethiopian Navy
KHATIBI, Hoshang, LT, Imperial Iranian Navy
MOEZZI, Massoud, LCDR, Imperial Iranian Navy
MOOMING, Santiparb, LTJG, Thailand Navy
NAKAMURA, Fumimaro, LTJG, Japanese Maritime Self Defense Force
ONG, Pablo S., LTJG, Republic of Philippines Navy
SALAZAR, Luis, LCDR, Ecuadorian Navy
SAHAMI, Mohamad Reza, LTJG, Imperial Iranian Navy
SAN, Kim Chong, LT, Republic of Korea Navy
SEDDIGH-TEHRAN, Manoutchehr, LTJG, Imperial Iranian Navy
SHUN-CHEN G. Liang, LCDR, Republic of China Navy
SITUMEANG, T. D. V., LT, Indonesian Navy
TALEON, Oscar J., LTJG, Republic of Philippines Navy
TAM, Nguyen, LT, Vietnamese Navy
TESFAYE, Makoya, LT, Imperial Ethiopian Navy
YUN, Tong Hwi, LCDR, Republic of Korea Navy

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CARLSON, Howard L., LCDR, USN
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DE GRESS, Francis B., III, LT, USN
DENNIS, Richard L., CAPT, USMC
DENTON, Dougles J., LT, USN
DONOVAN, Neil, LT, USN
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EVANS, James A., LT, USN
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GAGE, Robert J., LT, USNR
GENTZ, Richard C., LT, USN
HOGAN, Walter V., LCDR, USN
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HYATT, Leo G., LT, USN
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KOMP, Richard L., LT, USN
MAYFIELD, Douglas S., LT, USN
MELVIN, Edmund W., LT, USN
MILLER, Wayne W., LT, USN
NAGEL, "L" "D," LT, USN
PARKER, Elton C., Jr., LT, USN
RILEY, Thomas R., Jr., LT, USN
ROGERS, John A., II, CAPT, USMC
SLINGERLAND, Raymond D., LT, USN
SOLLIDAY, Robert E., CAPT, USMC
STURM, Paul M., LT, USN
WEILAND, Robert F., LT, USN
WHITE, Laurence A., Jr., LT, USN

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BROWNING, Robert B., LT, USN
CRINKLAW, Douglas L., LCDR, USN
DOWER, John J., LT, USN
DULIK, Andrew F., LT, USN
GAMBOA, John F., LT, USN
GILBERT, Marshall E., LT, USCG
HARDEN, Thad H., LT, USN
JAYNES, David W., LT, USN
JEROME, John D., LT, USN
KAUFFMAN, Thomas M., MAJ, USMC
LeBLANC, Thomas D., LT, USN
LEWIS, David E., LCDR, USN

MALONE, Ronald G., LT, USCG
MARBOTT, Henry W., LCDR, USN
McMASTER, David S., LT, USN
McNALLY, John H., LCDR, USN
MORGAN, John R., LT, USN
MOTT, George E., III, LT, USN
OLSON, Ross S., LT, USN
OWEN, Ernest E., LT, USN
PUCKETT, Eugene R., MAJ, USMC
RUNYON, Richard E., LCDR, USN
SCAMEHORN, Russell B., LT, USN
SMYTH, Thomas J., CAPT, USMC
TELFER, Larry E., LT, USCG
THOMAS, John D., LT, USN
WARREN, George F., CAPT, USMC
WHITE, Robert W., LT, USN
WORLEY, Joel K., LT, USN

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

ALEXANDROPOULOS, Vasilios L., LT, Royal Hellenic Navy
ALVAREZ, Marcos I., LT, USN
AUDILET, Garland O., LT, USN
BENNETT, Raymond D., LT, USN
BIELE, Charles E., Jr., LT, USN
BLAIR, Peter S., LT, USN
BLUNDELL, Peveril, LCDR, USN
BOYNE, Peter B., LT, USN
BRITO, Augusto S. Ascanio, LCDR, Venezuelan Navy
BROWN, Randall R., LT, USN
BUELL, Thomas B., LT, USN
BUTTERFIELD, Frederick D., LT, USN
CHURCH, Clifford E., Jr., LCDR, USN
CLARK, James M., LT, USN
DARBY, Thomas E., Jr., LT, USN
DEMAREST, Joseph G., III, LT, USN
DENNIS, Jefferson R., Jr., LT, USN
DYKES, James E. J., LT, USN
EDDLEMAN, Harold E., LT, USN
ELLIS, Hal R., III, LT, USN
FLEMING, Bruce S., LT, USN
GARRISON, Charles H., Jr., LT, USN
GIOKAS, Stavros K., LT, Royal Hellenic Navy
GODEFROY, Pierre L., LT, USN
GOODMAN, Michael "E," LT, USN
GREER, Roger W., CAPT., USMC
HEYDUCK, William R., LT, USN
HOLT, John A., III, LT, USN
HOWE, Frederic N., Jr., LT, USN
HUNTER, Harold C., LT, USN
INGRAM, Ronald F., LT, USN
ISHIHARA, Iwao, LT, Japanese Maritime Self Defense Force
KING, James W., LT, USN
LAMORE, James F., LCDR, USN
MAHONY, Terrence M., LT, USN
MARTIN, Donald L., LT, USN
McMANES, Kenmore R., LT, USN
MIELDAZIS, Richard J., LT, USN
MUNN, Robert J., Jr., LT, USN
RALSTON, Wesley L., CDR, USN
RAU, Ronald E., LT, USN
ROBINSON, Kenneth F., LT, USN
SANCHEZ-CARRION, Mario E., LT, Peruvian Navy
SARACCO, Robert L., LT, USN
SAWYER, Tommy D., LT, USN
SEIGENTHALER, Thomas U., LT, USN
SIBLEY, David N., LT, USN
SILVERMAN, Arnold M., LCDR, USN
STONE, Lowell P., LT, USN
STOODLEY, Francis H., LT, USN
WALKER, Thaddeus O., Jr., LT, USN
WATERS, Ronald L., LT, USN
WHITMIRE, Robert L., LT, USN
WILLIAMS, John A., LCDR, Royal Canadian Navy
WILLIAMS, James R., LT, USN
WILSON, David G., LT, USN
WOODS, Francis G., LT, USN
ZEITLER, William W., LT, USN

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BOND, Charles S., LT, USN
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BROWN, Kenneth C., LT, USN
BROWN, Robert H., LCDR, USN
BURGERT, Reginald D., LCDR, USN
CARLSON, Walter G., LT, USN
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COLE, Milton J., LT, USN
CONNERTON, James E., Jr., LT, USN
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DIXON, Ned E., LT, USN
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HOGENDOBLER, Clyde K., LT, USN
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KOTAKI, Kunio, LT, Japanese Maritime Self Defense Force
LANING, Clifford L., LT, USN
LIPSCOMB, Jack C., LT, USN
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SMEDS, James H., CDR, USN
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